APPENDIX A

COST ANNUALIZATION MODEL

This appendix provides an overview of the cost annualization model used by EPA. As discussed in Section 4 of this report, the annualization model calculates four types of compliance costs for a model CAFO:

- Present value of expenditures—before-tax basis
- Present value of expenditures—after-tax basis
- Annualized cost—before-tax basis
- Annualized cost—after-tax basis

The following sections present the input data and assumptions (Section A.1) and provide details about the workings of the annualization model (Section A.2). All tables in this Appendix are provided at the end of Appendix H.

A.1 INPUT DATA SOURCES

There are four key data inputs to the cost annualization model, including:

- Capital and O&M costs (including startup, recurring, and annual O&M costs)
- Depreciable life of the asset
- Discount rate
- Marginal tax rate

The *capital and O&M* costs that EPA uses in the cost annualization model are developed by EPA. The capital cost is the initial investment needed to purchase and install the structure; it is a one-time cost. The O&M cost is the annual cost of operating and maintaining the structure. O&M costs can be incurred in the first year (startup O&M costs), in periodic intervals (recurring O&M costs), or every year of the structure's operation (annual O&M costs).

The *depreciable life of the asset* refers to EPA's assumption on the time period used to depreciate capital improvements that are made due to the proposed CAFO regulations.

EPA's annualization model uses a real *discount rate* of 7 percent, as recommended by the Office of Management and Budget (OMB) (OMB, 1992). EPA assumes this input to be a real interest rate and therefore it is not adjusted for inflation.

The *marginal tax rate* (used to compute tax shield) depends on the amount of taxable earnings (estimated as net cash income minus depreciation plus value of inventory) at the model CAFO. Inputs to the cost annualization model to calculate an average operation's tax shield include both federal and state tax rates.

Additional information about compliance cost estimates and development of the model CAFOs is provided in Section 4 of this report. Detailed information about the costs used as inputs to the annualization model is provided in the *Development Document* (USEPA, 2000a).

Section A.1.1 below discusses the tax rate and Section A.1.2 discusses the depreciation method of the annualization model schedule in more detail.

A.1.1 Marginal Tax Rate

EPA conducts its financial analysis at the CAFO level using representative average models. The cost annualization model uses as inputs both federal and state tax rates to calculate an average operation's tax shield (see Table A-3 for sample worksheet). For this analysis, EPA uses federal and state corporate income tax rates because it is not possible to definitively identify whether CAFOs represented by each model pay taxes at the corporate or the individual rate.

Table A-3 lists the range of federal tax rates that EPA assumes for this analysis that are attributed to model CAFOs based on estimated taxable earnings. As shown, federal tax rates range from 15 percent to 34 percent, depending on the amount of taxable income at a facility (CCH, 1999b). As an example, using these rates, model CAFOs with earnings greater than or equal to $335,000 would be assigned the federal tax rate of 34 percent; model CAFOs with earnings greater than or equal to $100,000 but less than $335,000 would be assigned a tax rate of 28.3 percent. Examples of taxable income levels at EPA's model CAFOs are presented in Sections 6 through 8 that show average income statements for each sector.

Table A-1 lists each state's top corporate tax rates, as well as rates on individual income (CCH, 1999a and CCH, 1995). The cost annualization model refers to reported average state tax rates, however, because of the uncertainty over which state tax rate to apply to a given model CAFO, EPA uses the national average across all states. Table A-1 lists the national average value that EPA assumes for this analysis (CCH, 1999a and CCH, 1995). As shown, the average national rates are 6.6 percent (corporate income) and 5.8 percent (personal income). As discussed previously, EPA uses the higher corporate income tax rate for this analysis.

Table A-1. State Income Tax Rates

State	Corporate Income Tax Rate	Basis for States With Graduated Tax Tables	Personal Income Tax Upper Rate	Basis for States With Graduated Tax Tables
Alabama	5.00%		5.00%	$3,000+
Alaska	9.40%	$90,000+	0.00%	
Arizona	9.00%		6.90%	$150,000+
Arkansas	6.50%	$100,000+	7.00%	$25,000+
California	9.30%		11.00%	$215,000+
Colorado	5.00%		5.00%	
Connecticut	11.50%		4.50%	
Delaware	8.70%		7.70%	$40,000+
Florida	5.50%		0.00%	
Georgia	6.00%		6.00%	$7,000+
Hawaii	6.40%	$100,000+	10.00%	$21,000+
Idaho	8.00%		8.20%	$20,000+
Illinois	4.80%		3.00%	
Indiana	3.40%		3.40%	
Iowa	12.00%	$250,000+	9.98%	$47,000+
Kansas	4.00%	$50,000+	7.75%	$30,000+
Kentucky	8.25%	$250,000+	6.00%	$8,000+
Louisiana	8.00%	$200,000+	6.00%	$50,000+
Maine	8.93%	$250,000+	8.50%	$33,000+
Maryland	7.00%		6.00%	$100,000+
Massachusetts	9.50%		5.95%	
Michigan	2.30%		4.40%	
Minnesota	9.80%		8.50%	$50,000+
Mississippi	5.00%	$10,000+	5.00%	$10,000+
Missouri	6.25%		6.00%	$9,000+
Montana	6.75%		11.00%	$63,000+
Nebraska	7.81%	$50,000+	6.99%	$27,000+
Nevada	0.00%		0.00%	
New Hampshire	7.00%		0.00%	

Table A-1. State Income Tax Rates (continued)

State	Corporate Income Tax Rate	Basis for States With Graduated Tax Tables	Personal Income Tax Upper Rate	Basis for States With Graduated Tax Tables
New Jersey	7.25%		6.65%	$75,000+
New Mexico	7.60%	$1 Million+	8.50%	$42,000+
New York	9.00%		7.88%	$13,000+
North Carolina	7.75%		7.75%	$60,000+
North Dakota	10.50%	$50,000+	12.00%	$50,000+
Ohio	8.90%	Based on Stock Value	7.50%	$200,000+
Oklahoma	6.00%		7.00%	$10,000+
Oregon	6.60%		9.00%	$5,000+
Pennsylvania	9.90%	1997 and thereafter	2.80%	
Rhode Island	9.00%		10.40%	$250,000+
South Carolina	5.00%		7.00%	$11,000+
South Dakota	0.00%		0.00%	
Tennessee	6.00%		0.00%	
Texas	0.00%		0.00%	
Utah	5.00%		7.20%	$4,000+
Vermont	8.25%	$250,000+	9.45%	$250,000+
Virginia	6.00%		5.75%	$17,000+
Washington	0.00%		0.00%	
West Virginia	9.00%		6.50%	$60,000+
Wisconsin	7.90%		6.93%	$20,000+
Wyoming	0.00%		0.00%	
Average:	6.61%		5.84%	

Source: CCH, 1999a and 1995.
Basis for rates is reported to nearest $1,000. Personal income tax rates for Rhode Island and Vermont based on federal tax (not taxable income). Tax rates given here are equivalents for highest personal federal tax rate.

The cost annualization model can incorporate variable tax rates according to the level of income to address differences between small and large model CAFOs. For example, a large model CAFO might have a combined tax rate of 40.6 percent (34 percent federal rate plus 6.6 percent state rate). After tax shields, this model CAFO would pay 59.4 cents for every dollar of incremental animal waste management costs. A small model CAFO might be in the 21.6 percent tax rate (15 percent federal rate plus 6.6 percent state rate). After tax shields, the small model CAFO would pay 78.4 cents for every dollar of incremental animal waste management costs. The net present value of after-tax cost is used in the CAFO level impact analysis because it reflects the impact the business would actually see in its net income.[1]

A.1.2 Depreciation Method

EPA uses the Modified Accelerated Cost Recovery System (MACRS) to depreciate capital investments after examining three alternatives, including MACRS, straight-line depreciation, and Section 179 of the Internal Revenue Code. MACRS allows businesses to depreciate a higher percentage of an investment in the early years, and a lower percentage in the later years. In contrast, straight-line depreciation writes off a constant percentage of the investment each year. MACRS offers companies a financial advantage over the straight-line method because a model CAFO's taxable income may be reduced under MACRS by a greater amount in the early years when the time value of money is greater. EPA also considered using the Internal Revenue Code Section 179 provision to elect to expense up to $17,500 in the year the investment is placed in service, assuming that the investment costs do not exceed $200,000 (IRS, 1999a). However, EPA assumes that this provision is already applied to other investments at the CAFO.

To determine the recovery period of depreciable property, IRS identifies asset classes based on the activity in which the property is being used. If there is not an activity that matches the use then IRS provides classes for specific depreciable assets that are used across multiple business activities such as office furniture, information systems, and automobiles. Under MACRS, the cost of property is recovered over a set period. The recovery period is based on the property class to which your property is assigned. If the property of interest is not identified by the IRS then it generally has a recovery period of 7 years (IRS, 1999b).

The capital costs required by this regulation fall across three IRS asset classes including: land improvements (15 year recovery period), agriculture (7 year recovery period), and single purpose agricultural or horticultural structures (10 year recovery period). Table A-2 presents these IRS asset classes as well as the capital costs associated with them. EPA has identified the appropriate class for each type of cost and has judged that a 10-year time frame is appropriate for this analysis for the following reasons:

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[1] The cost annualization model does not consider tax shields on interest paid to finance animal waste management investments. The cost annualization model assumes a cost to the operation to use the money (the discount/interest rate), whether the money is paid as interest or is the opportunity cost of internal funding. Tax shields on interest payments are not included in the cost annualization model because it is not known what mix of debt and capital an operation will use to finance the cost of incremental animal waste management investments and to maintain a conservative estimate of the after-tax annualized cost.

A 10-year depreciation time frame is consistent with the 10-year property classification of a single purpose livestock structure which is defined under Section(i)(13)(B) as any enclosure or structure specifically designed, constructed and used for housing raising and feeding a particular kind of livestock including their produce or for housing the equipment necessary for the housing rasing and feeding of livestock (IRS, 1999a).

A 10 year depreciation time frame is a fairly conservative assumption considering that some assets such as land improvements have a longer 15-year time frame and others such as agricultural equipment have a shorter 7-year time frame.

This assumption provides a uniform time frame for use in the annualization model and prevents the use of separate annualization calculations for individual capital costs.

A 10-year time frame is consistent with the practice of cost-share programs which typically organize contracts over 5- to 10-year periods (USDA, 1999).

EPA conducted initial sensitivity analyses of the annualization model using initial cost estimates and determined that the differences between using a 7-, 10-, or 15-year time frame for depreciation did not result in large changes in annualized costs.

A.2 SAMPLE COST ANNUALIZATION SPREADSHEET

Table A-3 shows a sample cost annualization worksheet. The top of the spreadsheet shows the data inputs described in Section A.1. The spreadsheet contains numbered columns that calculate the before- and after-tax annualized cost of the investment to the CAFO. Column 1 of Table A-3 lists each year of the investment's life span, from its installation through its 10-year depreciable lifetime (shown over years 1 through 11, since a mid-year convention is used).

Column 2 of Table A-3 represents the percentage of the capital costs that can be written off or depreciated each year. These rates are based on the MACRS and are taken from CCH, 1999b. Multiplying these depreciation rates by the capital cost gives the annual amount the model CAFO may depreciate, which is listed in Column 3. EPA uses depreciation expense to offset annual income for tax purposes; Column 4 shows the tax shield provided from the depreciation expense—the overall tax rate times the depreciation amount for the year.

Column 5 of Table A-3 is the annual O&M expense. Due to the mid-year convention assumption for depreciation, Year 1 and Year 11 show only six months of annual O&M costs. Year 1 O&M also includes the startup O&M cost. Years 2 through 10 include annual O&M plus recurring O&M costs for every third and fifth year. Column 6 is the tax shield or benefit provided from expensing the O&M costs.

Table A-2. IRS Asset Class Lives and Recovery Periods Relevant for the Annualization of Capital Costs

Asset Class	Description of Assets Included	Recovery Period (in years)		Sample Capital Costs (Beef/Dairy Facilities)	Sample Capital Costs (Beef/Dairy Facilities)
		Class Life	MACRS (GDS)		
00.3	**Land Improvements:** Includes improvements directly to or added to land, whether such improvements are section 1245 property[1] or section 1250 property[2], provided such improvement are depreciable. Examples of such assets might include sidewalks, roads, canals, waterways, drainage facilities, sewers (not including municipal sewers in Class 51), wharves and docks, bridges, fences, landscaping shrubbery, or radio and television transmitting towers. Does not include land improvements that are explicitly includes in any other class, and buildings and structural components as defined in section 1.48-1(e) of the regulations. Excludes public utility initial clearing and grading land improvements as specified in Rev. Rul. 72-403, 1972-2 C.B. 102.	20	15	- Earthen settling basin - Concrete settling basin - Storage pond (“regular” and clay lined) - Vegetated filter strip (including wastewater distribution system) - Concrete pad to store dry manure	- Trenching to divert stormwater around structures - Lagoon liner - Groundwater monitoring well
01.1	**Agriculture:** Includes machinery and equipment, grain bins, and fences but no other land improvements, that are used in the production of crops or plants, vines, and trees; livestock; the operation of farm dairies, nurseries, greenhouses, sod farms, mushroom cellars, cranberry bogs, apiaries, and fur farms; the performance of agriculture, animal husbandry, and horticultural services.	10	7	- Windrow turning equipment (composting) - Long stem dial thermometer (composting) - Lagoon marker - Scale for manure spreader calibration - Irrigation center pivot device - Truck (under solid waste and slurry waste transport options)	- Soil auger/sampler - Manure sampler - Scale for manure spreader calibration - Lagoon marker - Disk harrow for surface incorp. - Manure injector - Center pivot for irrigation - Truck for transporting manure - Storage for poultry litter
01.4	**Single purpose agricultural or horticultural structures (within the meaning of section 168(l)(13) of the code)**	15	10		- Mortality composting facility

Source: IRS, 1999b.

1/ Section 1245 property: Property that is or has been subject to an allowance for depreciation or amortization. Section 1245 property includes personal property, single purpose agricultural and horticultural structures, storage facilities used in connection with the distribution of petroleum or primary products of petroleum, and railroad grading or tunnel bores.

2/ Section 1250 property: Real property (other than section 1245 property) which is or has been subject to an allowance for depreciation.

Table A-3. Cost Annualization Model

Inputs

Initial capital cost	$100,000	
Annual O&M Cost	$10,000	
Startup O&M Cost	$1,000	
Recurring O&M Cost	$500 (3 year)	$1,500 (5 year)
Real discount rate	7.0%	
Taxable income	$400,000	
Marginal income tax rate		
Federal	34.0%	
State	6.6%	
Combined	40.6%	

Federal Corp. Tax Table:

If Taxable Earnings are:			then the Federal tax rate is:	Average Effective Tax Rate
>= $0	and	< $50,000	→	15.0%
>= $50,000	and	< $75,000	→	16.7%
>= $75,000	and	< $100,000	→	20.4%
>= $100,000	and	< $335,000	→	28.3%
>= $335,000			→	34.0%

1 Year	2 Depreciation Rate	3 Depreciation for Year	4 Tax Shield from Dep.	5 O&M Cost	6 O&M Tax Shield	7 Cost-Share	8 Manure Offset	9 Cash Outflow	10 Cash Outflow After Tax Sh.
1	10.00%	$10,000	$4,061	$6,000	$2,437	$1,000	$500	$104,500	$98,002
2	18.00%	$18,000	$7,310	$10,000	$4,061	$1,000	$500	$8,500	($2,871)
3	14.40%	$14,400	$5,848	$10,500	$4,264	$1,000	$500	$9,000	($1,112)
4	11.52%	$11,520	$4,678	$10,000	$4,061	$1,000	$500	$8,500	($239)
5	9.22%	$9,220	$3,744	$11,500	$4,670	$1,000	$500	$10,000	$1,586
6	7.37%	$7,370	$2,993	$10,500	$4,264	$1,000	$500	$9,000	$1,743
7	6.55%	$6,550	$2,660	$10,000	$4,061	$1,000	$500	$8,500	$1,779
8	6.55%	$6,550	$2,660	$10,000	$4,061	$1,000	$500	$8,500	$1,779
9	6.56%	$6,560	$2,664	$10,500	$4,264	$1,000	$500	$9,000	$2,072
10	6.55%	$6,550	$2,660	$11,500	$4,670	$1,000	$500	$10,000	$2,670
11	3.28%	$3,280	$1,332	$5,000	$2,031	$0	$500	$4,500	$1,137
Sum	100.00%	$100,000	$40,610	$105,500	$42,844	$10,000	$5,500	$190,000	$106,546
Present value		$73,443	$29,825	$71,718	$29,125	$7,024	$3,749	$154,403	$95,453

	Before Tax Sh.	After Tax Sh.
Present value of incremental costs	$154,403	$95,453
Annualized Cost	$20,591	$12,729

Notes: This spreadsheet assumes that a modified accelerated cost recovery system (MACRS) is used to depreciate capital expenditures. Depreciation rates are from 2000 U.S. Master Tax Guide for 10-year property and mid-year convention (CCH, 1999b).

Columns 7 and 8 represent negative costs that should be evaluated when considering compliance costs for model CAFOs, including payments from federal, state, or local cost-share programs and offsets from the change in manure use.

Column 9 lists a model CAFO's annual cash outflow, or total expenses, associated with the additional animal waste management. Total expenses include capital costs, assumed to be incurred during the first year when the structure is installed, plus each year's O&M expense.

Column 10 lists the annual cash outflow less the tax shields from the O&M expenses and depreciation; a model CAFO will recover these costs in the form of reduced income taxes. The sum of the 11 years of after-tax expenses is $106,546 (1997 dollars). The equation EPA uses to calculate the present value of cash flow is :

$$NPV = v_1 + \sum_{i=2}^{n} \frac{v_i}{(1+r)^{i-1}}$$

Where:

$v_1 \ldots v_n$ = series of cash flows
r = interest rate
n = number of cash flow periods
i = current iteration

EPA uses the present value of the after-tax cash outflow in the CAFO level impact analysis to calculate the post-regulatory present value of future earnings for a model CAFO.

EPA transforms the present value of the cash outflow into a constant annual payment for use as the annualized model CAFO's compliance cost. Column 9 calculates the annualized cost as a 10-year annuity that has the same present value as the total cash outflow. The annualized cost represents the annual payment required to finance the cash outflow after tax shields. In essence, paying the annualized cost each year and paying the amounts listed in Column 8 for each year are equivalent. EPA calculates the annualized cost as:

$$\text{Annualized Cost} = \text{Present value of cash outflows} * \frac{\text{real discount rate}}{1 - (\text{real discount rate} + 1)^{-n}}$$

where n is the number of payment periods.

In the example used in Table A-3, based on the capital investment of $100,000, startup O&M costs of $1,000, 3-year recurring O&M costs of $500, 5-year recurring O&M costs of $1,500, annual O&M costs of $10,000 per year, a tax rate of 40.6 percent, and a real discount rate of 7 percent, the model CAFO's annualized cost is $20,591 on a pre-tax basis and $12,729 on a post-tax basis.[2]

EPA uses the pre-tax annualized cost to calculate the total social cost of the regulation (presented in Section 10). This approach incorporates the cost to industry for the purchase, installation, and operation of additional animal waste management structures, and also federal and state government from lost tax revenues. (Every tax dollar that a business does not pay due to a tax shield is a tax dollar lost to the government.)

EPA uses the post-tax annualized cost to reflect what a business actually pays to comply with incremental animal waste management requirements (presented in Section 5). The post-tax present value of incremental animal waste management expenditures is used in the CAFO level impact analysis.

A.3 ANNUALIZED COMPLIANCE COSTS

Tables A-4 through A-11 show EPA's estimated post-tax annualized costs to regulated CAFOs to comply with the proposed revisions to the CAFO regulations. Annualized costs are shown in 1997 dollars and are expressed on a per-animal (inventory) basis. EPA estimates per-animal costs for operations that raise fed cattle, veal, heifers, milk cows, hogs (both farrow-finish and grow-finish systems), broilers, egg laying hens (both liquid and dry manure systems), and turkeys. The tables show these costs for each of the seven ELG technology options considered by EPA during the development of this rulemaking. Costs to confinement operations with less than 300 or 500 AU that may be designated as CAFOs are developed by scaling the estimated compliance costs for the available "medium" and "large" CAFO models. (See Section 2 for information on expected designated facilities under each co-proposed alternative.) The resulting costs–derived on a per-head basis–are adjusted by the average head counts at operations with fewer than 500 AU or 300 AU to derive the annualized per-facility compliance cost. Costs for CAFOs with fewer than 500 AU or 300 AU assume that these operations have sufficient cropland for all on-farm nutrients generated (identified in the cost model as Category 1 costs).

[2] There are two ways to calculate post-tax annualized cost. One is to calculate the annualized cost as the difference between the annuity value of the cash flows (Column 9) and the tax shields (Columns 4 and 6). The second is to calculate the annuity value of the cash flows after tax shields (Column 10). Both methods yield the same result.

Table A-4
Total Annualized Compliance Costs per Head for Option 1

Sector/Model	Head	Category 1	Category 2	Category 3
Beef				
MW Region				
Small	112	$16.08	NA	NA
Medium 1	455	$16.69	$16.49	$5.17
Medium 2	777	$10.41	$10.52	$2.56
Large 1	1,877	$1.36	$9.40	$0.60
Large 2	30,003	$0.85	$3.94	$0.16
CE Region				
Medium 1	455	$15.55	$15.53	$5.11
Medium 2	777	$9.58	$10.51	$2.51
Large 1	1,877	$1.09	$15.32	$0.52
Large 2	30,003	$0.57	$4.71	$0.08
Dairy				
PA Region				
Medium 1	235	$16.84	$23.97	$13.76
Medium 2	460	$10.77	$41.79	$8.81
Large 1	1,419	$5.77	$39.19	$5.00
MW Region				
Small	200	$16.42	NA	NA
Medium 1	235	$14.77	$16.65	$10.60
Medium 2	460	$9.39	$24.30	$6.66
Large 1	1,419	$4.50	$22.35	$3.60
Veal				
MW Region				
Medium 1	400	$3.61	$2.76	$2.50
Medium 2	540	$2.66	$2.03	$1.84
Heifers				
PA Region				
Medium 1	400	$13.76	$16.85	$5.67
Medium 2	750	$8.50	$8.63	$3.28
Large 1	1,500	$1.06	$1.29	$0.75
MW Region				
Medium 1	400	$13.72	$16.84	$5.60
Medium 2	750	$8.65	$9.44	$3.23
Large 1	1,500	$0.95	$1.04	$0.67

Table A-4 (continued)
Total Annualized Compliance Costs per Head for Option 1

Sector/Model	Head	Category 1	Category 2	Category 3
Hogs (a)				
MW Region (GF)				
Medium 1a	900	$0.70	$1.52	$10.20
Medium 1b	1,422	$0.47	$5.47	$9.75
Medium 2	2,124	$0.29	$1.46	$8.20
Large 1	3,417	$0.09	$3.43	$8.81
Large 2	10,029	$0.04	$3.86	$7.81
MA Region (GF)				
Medium 1a	963	$0.56	$6.80	$10.17
Medium 1b	1,521	$0.40	$3.50	$9.80
Medium 2	2,184	$0.31	$6.63	$9.60
Large 1	3,554	$0.09	$7.36	$8.80
Large 2	8,893	$0.04	$6.18	$7.82
MW Region (FF)				
Small	750	$0.48	NA	NA
Medium 1a	814	$0.77	$1.70	$9.01
Medium 1b	1,460	$0.46	$1.07	$8.41
Medium 2	2,152	$0.29	$0.71	$7.08
Large 1	3,444	$0.09	$0.48	$7.56
Large 2	13,819	$0.03	$4.02	$6.16
MA Region (FF)				
Medium 1a	846	$0.62	$1.51	$8.97
Medium 1b	1,518	$0.40	$5.60	$8.46
Medium 2	2,165	$0.31	$6.04	$8.26
Large 1	3,509	$0.09	$5.65	$7.56
Large 2	17,118	$0.03	$2.23	$6.15
Broilers				
SO Region				
Medium 1a	36,634	$0.09	$0.09	$0.08
Medium 1b	51,362	$0.09	$0.08	$0.07
Medium 2	73,776	$0.08	$0.08	$0.07
Large 1	117,581	$0.08	$0.07	$0.06
Large 2	281,453	$0.07	$0.06	$0.05
MA Region				
Medium 1a	36,796	$0.09	$0.09	$0.08
Medium 1b	51,590	$0.09	$0.08	$0.07
Medium 2	73,590	$0.08	$0.08	$0.07
Large 1	115,281	$0.08	$0.07	$0.07
Large 2	303,155	$0.06	$0.06	$0.05
Layers				
Wet SO Region				
Small	1,000	$0.14	NA	NA
Medium 2	3,654	$0.07	$0.55	$0.40
Large 1	86,898	$0.01	$0.27	$0.16
Dry SO Region				
Medium 1a	32,375	$0.03	$0.03	$0.02
Medium 1b	44,909	$0.03	$0.02	$0.02
Medium 2	97,413	$0.02	$0.02	$0.02
Large 1	293,512	$0.02	$0.02	$0.02
Large 2	884,291	$0.02	$0.02	$0.02
Dry MW Region				
Medium 1a	37,906	$0.03	$0.03	$0.02
Medium 1b	52,582	$0.03	$0.03	$0.02
Medium 2	97,484	$0.02	$0.02	$0.02
Large 1	279,202	$0.02	$0.02	$0.02
Large 2	1,229,095	$0.02	$0.02	$0.02
Turkeys				
MA Region				
Medium 1a	18,539	$0.13	$0.13	$0.09
Medium 1b	31,267	$0.11	$0.11	$0.07
Medium 2	45,193	$0.09	$0.08	$0.06
Large 1	97,111	$0.08	$0.07	$0.05
MW Region				
Medium 1a	18,092	$0.17	$0.17	$0.13
Medium 1b	30,514	$0.15	$0.15	$0.12
Medium 2	45,469	$0.13	$0.13	$0.10
Large 1	158,365	$0.12	$0.12	$0.10

(a) Two categories of hog farms are included: grower-finish (GF) and farrow-finish (FF).

Table A-5
Total Annualized Compliance Costs per Head for Option 2

Sector/Model	Head	Category 1	Category 2	Category 3
Beef				
MW Region				
Small	112	$17.86	NA	NA
Medium 1	455	$18.34	$21.56	$5.17
Medium 2	777	$11.96	$14.54	$2.56
Large 1	1,877	$1.61	$8.80	$0.60
Large 2	30,003	$0.93	$4.12	$0.16
CE Region				
Medium 1	455	$25.63	$35.32	$5.11
Medium 2	777	$19.21	$26.55	$2.51
Large 1	1,877	$6.44	$14.97	$0.52
Large 2	30,003	$2.94	$10.48	$0.08
Dairy				
PA Region				
Medium 1	235	$21.42	$27.81	$13.76
Medium 2	460	$14.62	$30.66	$8.81
Large 1	1,419	$8.07	$29.26	$5.00
MW Region				
Small	200	$19.39	NA	NA
Medium 1	235	$17.97	$21.60	$10.60
Medium 2	460	$12.20	$22.68	$6.66
Large 1	1,419	$6.53	$18.05	$3.60
Veal				
MW Region				
Medium 1	400	$7.20	$2.76	$2.50
Medium 2	540	$3.72	$2.03	$1.84
Heifers				
PA Region				
Medium 1	400	$17.55	$20.87	$5.67
Medium 2	750	$11.61	$14.38	$3.28
Large 1	1,500	$2.45	$5.03	$0.75
MW Region				
Medium 1	400	$14.98	$18.78	$5.60
Medium 2	750	$9.64	$11.13	$3.23
Large 1	1,500	$1.21	$2.23	$0.67

Table A-5 (continued)
Total Annualized Compliance Costs per Head for Option 2

Sector/Model	Head	Category 1	Category 2	Category 3
Hogs (a)				
MW Region (GF)				
Medium 1a	900	$2.89	$3.52	$7.47
Medium 1b	1,422	$2.67	$6.78	$7.00
Medium 2	2,124	$2.15	$4.48	$5.90
Large 1	3,417	$1.94	$5.33	$6.20
Large 2	10,029	$1.69	$4.60	$5.48
MA Region (GF)				
Medium 1a	963	$3.09	$7.85	$7.34
Medium 1b	1,521	$2.89	$5.86	$7.21
Medium 2	2,184	$2.83	$7.07	$6.87
Large 1	3,554	$2.06	$6.78	$6.18
Large 2	8,893	$1.79	$5.61	$5.52
MW Region (FF)				
Small	750	$2.28	NA	NA
Medium 1a	814	$2.95	$3.87	$6.96
Medium 1b	1,460	$2.65	$4.74	$6.37
Medium 2	2,152	$2.15	$2.18	$5.35
Large 1	3,444	$1.93	$2.65	$5.61
Large 2	13,819	$1.53	$4.44	$4.58
MA Region (FF)				
Medium 1a	846	$3.15	$3.30	$6.92
Medium 1b	1,518	$2.93	$6.70	$6.33
Medium 2	2,165	$2.84	$7.03	$6.17
Large 1	3,509	$2.06	$6.13	$5.61
Large 2	17,118	$1.62	$3.65	$4.56
Broilers				
SO Region				
Medium 1a	36,634	$0.15	$0.10	$0.08
Medium 1b	51,362	$0.14	$0.09	$0.07
Medium 2	73,776	$0.13	$0.08	$0.07
Large 1	117,581	$0.13	$0.08	$0.06
Large 2	281,453	$0.11	$0.06	$0.05
MA Region				
Medium 1a	36,796	$0.13	$0.11	$0.08
Medium 1b	51,590	$0.13	$0.10	$0.07
Medium 2	73,590	$0.12	$0.10	$0.07
Large 1	115,281	$0.12	$0.09	$0.07
Large 2	303,155	$0.10	$0.07	$0.05
Layers				
Wet SO Region				
Small	1,000	$0.32	NA	NA
Medium 2	3,654	$0.24	$0.60	$0.39
Large 1	86,898	$0.15	$0.27	$0.15
Dry SO Region				
Medium 1a	32,375	$0.18	$0.04	$0.02
Medium 1b	44,909	$0.14	$0.04	$0.02
Medium 2	97,413	$0.15	$0.03	$0.02
Large 1	293,512	$0.18	$0.02	$0.02
Large 2	884,291	$0.00	$0.02	$0.02
Dry MW Region				
Medium 1a	37,906	$0.25	$0.05	$0.02
Medium 1b	52,582	$0.27	$0.04	$0.02
Medium 2	97,484	$0.23	$0.04	$0.02
Large 1	279,202	$0.19	$0.03	$0.02
Large 2	1,229,095	$0.00	$0.02	$0.02
Turkeys				
MA Region				
Medium 1a	18,539	$0.71	$0.29	$0.09
Medium 1b	31,267	$0.70	$0.23	$0.07
Medium 2	45,193	$0.61	$0.18	$0.06
Large 1	97,111	$0.57	$0.16	$0.05
MW Region				
Medium 1a	18,092	$0.83	$0.28	$0.13
Medium 1b	30,514	$0.79	$0.22	$0.12
Medium 2	45,469	$0.65	$0.18	$0.10
Large 1	158,365	$0.65	$0.15	$0.10

(a) Two categories of hog farms are included: grower-finish (GF) and farrow-finish (FF).

Table A-6
Total Annualized Compliance Costs per Head for Option 3

Sector/Model	Head	Category 1	Category 2	Category 3
Beef				
MW Region				
Small	112	$28.37	NA	NA
Medium 1	455	$29.60	$32.26	$15.87
Medium 2	777	$21.00	$23.29	$11.31
Large 1	1,877	$8.26	$15.31	$7.12
Large 2	30,003	$4.61	$7.79	$3.83
CE Region				
Medium 1	455	$31.74	$41.03	$10.81
Medium 2	777	$24.12	$31.25	$7.21
Large 1	1,877	$9.39	$17.82	$3.37
Large 2	30,003	$4.52	$12.06	$1.65
Dairy				
PA Region				
Medium 1	235	$48.23	$53.78	$39.72
Medium 2	460	$31.66	$47.34	$25.49
Large 1	1,419	$20.02	$41.09	$16.83
MW Region				
Small	200	$60.39	NA	NA
Medium 1	235	$58.74	$61.51	$50.50
Medium 2	460	$39.99	$50.07	$34.05
Large 1	1,419	$27.37	$38.76	$24.32
Veal				
MW Region				
Medium 1	400	$7.78	$2.91	$2.65
Medium 2	540	$4.75	$2.73	$2.54
Heifers				
PA Region				
Medium 1	400	$22.94	$27.72	$10.63
Medium 2	750	$15.41	$17.43	$6.86
Large 1	1,500	$5.35	$7.79	$3.51
MW Region				
Medium 1	400	$24.14	$27.49	$14.13
Medium 2	750	$16.11	$18.58	$9.37
Large 1	1,500	$5.74	$6.60	$5.04

Table A-6 (continued)
Total Annualized Compliance Costs per Head for Option 3

Sector/Model	Head	Category 1	Category 2	Category 3
Hogs (a)				
MW Region (GF)				
Medium 1a	900	$3.92	$4.44	$8.49
Medium 1b	1,422	$3.41	$7.44	$7.77
Medium 2	2,124	$2.67	$4.91	$6.38
Large 1	3,417	$2.36	$5.67	$6.62
Large 2	10,029	$1.94	$4.80	$5.74
MA Region (GF)				
Medium 1a	963	$3.92	$8.61	$8.26
Medium 1b	1,521	$3.54	$6.35	$7.79
Medium 2	2,184	$3.34	$7.48	$7.36
Large 1	3,554	$2.39	$7.06	$6.56
Large 2	8,893	$2.01	$5.78	$5.73
MW Region (FF)				
Small	750	$2.99	NA	NA
Medium 1a	814	$4.07	$4.90	$8.08
Medium 1b	1,460	$3.39	$5.42	$7.11
Medium 2	2,152	$2.66	$2.60	$5.83
Large 1	3,444	$2.35	$2.99	$6.03
Large 2	13,819	$1.76	$4.61	$4.82
MA Region (FF)				
Medium 1a	846	$4.07	$4.14	$7.73
Medium 1b	1,518	$3.53	$7.31	$6.90
Medium 2	2,165	$3.32	$7.44	$6.67
Large 1	3,509	$2.40	$6.40	$5.94
Large 2	17,118	$1.81	$3.79	$4.74
Broilers				
SO Region				
Medium 1a	36,634	$0.16	$0.11	$0.09
Medium 1b	51,362	$0.15	$0.10	$0.08
Medium 2	73,776	$0.14	$0.09	$0.08
Large 1	117,581	$0.14	$0.08	$0.07
Large 2	281,453	$0.11	$0.06	$0.05
MA Region				
Medium 1a	36,796	$0.15	$0.13	$0.10
Medium 1b	51,590	$0.14	$0.12	$0.09
Medium 2	73,590	$0.13	$0.11	$0.08
Large 1	115,281	$0.13	$0.10	$0.07
Large 2	303,155	$0.10	$0.07	$0.06
Layers				
Wet SO Region				
Small	1,000	$0.57	NA	NA
Medium 2	3,654	$0.36	$0.73	$0.51
Large 1	86,898	$0.15	$0.28	$0.16
Dry SO Region				
Medium 1a	32,375	$0.19	$0.05	$0.03
Medium 1b	44,909	$0.18	$0.04	$0.03
Medium 2	97,413	$0.15	$0.03	$0.02
Large 1	293,512	$0.10	$0.02	$0.02
Large 2	884,291	$0.00	$0.02	$0.02
Dry MW Region				
Medium 1a	37,906	$0.26	$0.06	$0.04
Medium 1b	52,582	$0.25	$0.05	$0.03
Medium 2	97,484	$0.23	$0.04	$0.02
Large 1	279,202	$0.00	$0.03	$0.02
Large 2	1,229,095	$0.00	$0.02	$0.02
Turkeys				
MA Region				
Medium 1a	18,539	$0.75	$0.32	$0.12
Medium 1b	31,267	$0.72	$0.25	$0.09
Medium 2	45,193	$0.62	$0.19	$0.07
Large 1	97,111	$0.58	$0.17	$0.05
MW Region				
Medium 1a	18,092	$0.83	$0.32	$0.17
Medium 1b	30,514	$0.81	$0.24	$0.15
Medium 2	45,469	$0.67	$0.19	$0.12
Large 1	158,365	$0.66	$0.16	$0.10

(a) Two categories of hog farms are included: grower-finish (GF) and farrow-finish (FF).

Table A-7
Total Annualized Compliance Costs per Head for Option 3A

Sector/Model	Head	Category 1	Category 2	Category 3
Beef				
MW Region				
Small	112	$80.06	NA	NA
Medium 1	455	$64.02	$67.24	$51.06
Medium 2	777	$47.97	$50.56	$38.69
Large 1	1,877	$27.46	$34.65	$26.50
Large 2	30,003	$15.88	$19.08	$15.12
CE Region				
Medium 1	455	$70.62	$80.32	$50.31
Medium 2	777	$54.64	$61.98	$38.06
Large 1	1,877	$30.06	$38.59	$24.19
Large 2	30,003	$16.65	$24.20	$13.79
Dairy				
PA Region				
Medium 1	235	$228.84	$235.23	$221.62
Medium 2	460	$148.83	$164.88	$143.21
Large 1	1,419	$100.45	$121.64	$97.44
MW Region				
Small	200	$228.08	NA	NA
Medium 1	235	$183.75	$187.38	$176.79
Medium 2	460	$126.14	$136.62	$120.80
Large 1	1,419	$88.44	$99.96	$85.57
Veal				
MW Region				
Medium 1	NA	NA	NA	NA
Medium 2	NA	NA	NA	NA
Heifers				
CE Region				
Medium 1	400	$58.34	$60.86	$46.71
Medium 2	750	$40.34	$43.96	$32.14
Large 1	1,500	$23.91	$27.14	$22.28
MW Region				
Medium 1	400	$53.46	$55.50	$44.33
Medium 2	750	$36.78	$39.57	$30.50
Large 1	1,500	$18.66	$20.16	$18.18

Table A-7 (continued)
Total Annualized Compliance Costs per Head for Option 3A

Sector/Model	Head	Category 1	Category 2	Category 3
Hogs (a)				
MW Region (GF)				
Medium 1a	900	$9.25	$8.89	$18.74
Medium 1b	1,422	$7.18	$11.04	$16.45
Medium 2	2,124	$5.19	$5.39	$13.09
Large 1	3,417	$4.63	$6.94	$13.35
Large 2	10,029	$3.30	$6.23	$11.07
MA Region (GF)				
Medium 1a	963	$8.92	$13.96	$18.53
Medium 1b	1,521	$7.00	$8.95	$16.40
Medium 2	2,184	$5.96	$11.16	$15.25
Large 1	3,554	$4.58	$10.83	$13.30
Large 2	8,893	$3.37	$8.61	$11.15
MW Region (FF)				
Small	750	$2.28	NA	NA
Medium 1a	814	$9.84	$9.58	$18.08
Medium 1b	1,460	$7.08	$6.55	$15.03
Medium 2	2,152	$5.16	$4.61	$11.94
Large 1	3,444	$4.62	$3.97	$12.09
Large 2	13,819	$2.94	$6.11	$9.08
MA Region (FF)				
Medium 1a	846	$9.63	$9.31	$17.98
Medium 1b	1,518	$7.00	$11.06	$15.06
Medium 2	2,165	$5.98	$10.59	$13.93
Large 1	3,509	$4.60	$9.13	$12.07
Large 2	17,118	$2.87	$4.26	$9.00
Broilers				
SO Region				
Medium 1a	36,634	$0.18	$0.13	$0.11
Medium 1b	51,362	$0.16	$0.12	$0.10
Medium 2	73,776	$0.15	$0.10	$0.09
Large 1	117,581	$0.14	$0.09	$0.08
Large 2	281,453	$0.11	$0.07	$0.06
MA Region				
Medium 1a	36,796	$0.17	$0.15	$0.12
Medium 1b	51,590	$0.15	$0.13	$0.10
Medium 2	73,590	$0.14	$0.12	$0.09
Large 1	115,281	$0.14	$0.11	$0.08
Large 2	303,155	$0.10	$0.07	$0.06
Layers				
Wet SO Region				
Small	1,000	$0.46	NA	NA
Medium 2	3,654	$0.57	$0.93	$0.72
Large 1	86,898	$0.18	$0.30	$0.18
Dry SO Region				
Medium 1a	32,375	$0.22	$0.07	$0.05
Medium 1b	44,909	$0.22	$0.06	$0.04
Medium 2	97,413	$0.15	$0.04	$0.03
Large 1	293,512	$0.02	$0.03	$0.02
Large 2	884,291	$0.00	$0.02	$0.02
Dry MW Region				
Medium 1a	37,906	$0.30	$0.08	$0.05
Medium 1b	52,582	$0.23	$0.06	$0.04
Medium 2	97,484	$0.24	$0.05	$0.03
Large 1	279,202	$0.00	$0.03	$0.02
Large 2	1,229,095	$0.00	$0.02	$0.02
Turkeys				
MA Region				
Medium 1a	18,539	$0.76	$0.36	$0.16
Medium 1b	31,267	$0.75	$0.28	$0.12
Medium 2	45,193	$0.53	$0.21	$0.09
Large 1	97,111	$0.92	$0.18	$0.07
MW Region				
Medium 1a	18,092	$0.87	$0.36	$0.22
Medium 1b	30,514	$0.85	$0.28	$0.18
Medium 2	45,469	$0.62	$0.21	$0.14
Large 1	158,365	$0.60	$0.17	$0.11

(a) Two categories of hog farms are included: grower-finish (GF) and farrow-finish (FF).

Table A-8
Total Annualized Compliance Costs per Head for Option 4

Sector/Model	Head	Category 1	Category 2	Category 3
Beef				
MW Region				
Small	112	$37.00	NA	NA
Medium 1	455	$38.77	$41.44	$25.04
Medium 2	777	$25.79	$28.08	$16.10
Large 1	1,877	$10.24	$17.29	$9.10
Large 2	30,003	$4.72	$7.90	$3.94
CE Region				
Medium 1	455	$40.91	$50.20	$19.98
Medium 2	777	$28.91	$36.04	$12.00
Large 1	1,877	$11.37	$19.80	$5.35
Large 2	30,003	$4.63	$12.17	$1.77
Dairy				
PA Region				
Medium 1	235	$66.89	$72.43	$58.38
Medium 2	460	$39.75	$55.43	$33.58
Large 1	1,419	$22.41	$43.49	$19.22
MW Region				
Small	200	$80.53	NA	NA
Medium 1	235	$76.50	$79.26	$68.26
Medium 2	460	$48.08	$58.16	$42.15
Large 1	1,419	$29.77	$41.16	$26.71
Veal				
MW Region				
Medium 1	400	$18.74	$13.87	$13.61
Medium 2	540	$12.86	$10.85	$10.66
Heifers				
PA Region				
Medium 1	400	$33.90	$37.00	$21.59
Medium 2	750	$20.97	$22.99	$12.42
Large 1	1,500	$8.28	$10.72	$6.43
MW Region				
Medium 1	400	$35.10	$37.32	$25.09
Medium 2	750	$21.67	$24.14	$14.94
Large 1	1,500	$8.22	$9.08	$7.52

Table A-8 (continued)
Total Annualized Compliance Costs per Head for Option 4

Sector/Model	Head	Category 1	Category 2	Category 3
Hogs (a)				
MW Region (GF)				
Medium 1a	900	$6.54	$7.06	$11.11
Medium 1b	1,422	$5.07	$9.09	$9.43
Medium 2	2,124	$3.61	$5.85	$7.32
Large 1	3,417	$3.24	$6.56	$7.50
Large 2	10,029	$2.21	$5.06	$6.01
MA Region (GF)				
Medium 1a	963	$8.31	$13.00	$12.65
Medium 1b	1,521	$6.32	$9.13	$10.57
Medium 2	2,184	$5.27	$9.42	$9.29
Large 1	3,554	$3.36	$8.03	$7.53
Large 2	8,893	$2.36	$6.12	$6.08
MW Region (FF)				
Small	750	$4.57	NA	NA
Medium 1a	814	$6.96	$7.80	$10.97
Medium 1b	1,460	$5.01	$7.03	$8.73
Medium 2	2,152	$3.58	$3.53	$6.76
Large 1	3,444	$3.23	$3.86	$6.90
Large 2	13,819	$1.94	$4.79	$4.99
MA Region (FF)				
Medium 1a	846	$9.07	$9.13	$12.72
Medium 1b	1,518	$6.32	$10.10	$9.69
Medium 2	2,165	$5.28	$9.39	$8.62
Large 1	3,509	$3.38	$7.38	$6.92
Large 2	17,118	$1.97	$3.96	$4.91
Broilers				
SO Region				
Medium 1a	36,634	$0.28	$0.24	$0.22
Medium 1b	51,362	$0.24	$0.19	$0.17
Medium 2	73,776	$0.20	$0.15	$0.14
Large 1	117,581	$0.17	$0.12	$0.11
Large 2	281,453	$0.12	$0.08	$0.07
MA Region				
Medium 1a	36,796	$0.27	$0.25	$0.22
Medium 1b	51,590	$0.23	$0.20	$0.17
Medium 2	73,590	$0.19	$0.17	$0.14
Large 1	115,281	$0.16	$0.14	$0.11
Large 2	303,155	$0.11	$0.08	$0.07
Layers				
Wet SO Region				
Small	1,000	$2.98	NA	NA
Medium 2	3,654	$1.59	$1.95	$1.74
Large 1	86,898	$0.19	$0.32	$0.20
Dry SO Region				
Medium 1a	32,375	$0.30	$0.17	$0.15
Medium 1b	44,909	$0.26	$0.13	$0.11
Medium 2	97,413	$0.18	$0.07	$0.05
Large 1	293,512	$0.11	$0.04	$0.03
Large 2	884,291	$0.00	$0.02	$0.02
Dry MW Region				
Medium 1a	37,906	$0.36	$0.16	$0.13
Medium 1b	52,582	$0.32	$0.12	$0.10
Medium 2	97,484	$0.27	$0.08	$0.06
Large 1	279,202	$0.20	$0.04	$0.03
Large 2	1,229,095	$0.00	$0.02	$0.02
Turkeys				
MA Region				
Medium 1a	18,539	$0.98	$0.56	$0.36
Medium 1b	31,267	$0.86	$0.39	$0.23
Medium 2	45,193	$0.70	$0.27	$0.15
Large 1	97,111	$0.62	$0.20	$0.09
MW Region				
Medium 1a	18,092	$1.07	$0.56	$0.41
Medium 1b	30,514	$0.95	$0.39	$0.29
Medium 2	45,469	$0.75	$0.27	$0.20
Large 1	158,365	$0.68	$0.18	$0.13

(a) Two categories of hog farms are included: grower-finish (GF) and farrow-finish (FF).

Table A-9
Total Annualized Compliance Costs per Head for Option 5

Sector/Model	Head	Category 1	Category 2	Category 3
Beef				
MW Region				
Small	112	$42.32	NA	NA
Medium 1	455	$49.02	$52.23	$35.85
Medium 2	777	$40.19	$42.74	$30.80
Large 1	1,877	$29.30	$36.45	$28.28
Large 2	30,003	$26.89	$30.37	$26.12
CE Region				
Medium 1	455	$58.44	$68.12	$37.92
Medium 2	777	$49.47	$56.76	$32.76
Large 1	1,877	$36.77	$45.28	$30.85
Large 2	30,003	$31.59	$39.08	$28.73
Dairy				
PA Region				
Medium 1	235	$45.02	$51.41	$37.36
Medium 2	460	$33.07	$49.32	$27.26
Large 1	1,419	$18.08	$38.17	$15.01
MW Region				
Small	200	$48.75	NA	NA
Medium 1	235	$47.64	$50.75	$40.26
Medium 2	460	$37.04	$48.77	$31.50
Large 1	1,419	$22.52	$33.19	$19.59
Veal				
MW Region				
Medium 1	400	$7.20	$2.76	$2.50
Medium 2	540	$3.72	$2.03	$1.84
Heifers				
PA Region				
Medium 1	400	$20.40	$23.68	$8.52
Medium 2	750	$13.30	$15.50	$4.97
Large 1	1,500	$3.30	$5.86	$1.60
MW Region				
Medium 1	400	$17.83	$22.75	$8.44
Medium 2	750	$11.33	$12.79	$4.92
Large 1	1,500	$1.95	$2.97	$1.42

Table A-9 (continued)
Total Annualized Compliance Costs per Head for Option 5

Sector/Model	Head	Category 1	Category 2	Category 3
Hogs (a)				
MW Region (GF)				
Medium 1a	900	$7.30	$6.03	$7.47
Medium 1b	1,422	$6.82	$8.72	$7.00
Medium 2	2,124	$5.69	$6.81	$5.90
Large 1	3,417	$5.68	$5.43	$6.20
Large 2	10,029	$5.02	$4.45	$5.48
MA Region (GF)				
Medium 1a	963	$7.53	$9.43	$7.34
Medium 1b	1,521	$7.09	$5.79	$7.21
Medium 2	2,184	$6.90	$8.55	$6.87
Large 1	3,554	$5.80	$7.55	$6.18
Large 2	8,893	$5.13	$4.97	$5.52
MW Region (FF)				
Small	750	$5.80	NA	NA
Medium 1a	814	$7.45	$6.64	$6.96
Medium 1b	1,460	$6.79	$6.03	$6.37
Medium 2	2,152	$5.68	$4.35	$5.35
Large 1	3,444	$5.68	$6.19	$5.61
Large 2	13,819	$4.63	$5.44	$4.58
MA Region (FF)				
Medium 1a	846	$7.69	$5.87	$6.92
Medium 1b	1,518	$7.13	$8.18	$6.33
Medium 2	2,165	$6.91	$8.10	$6.17
Large 1	3,509	$5.80	$7.05	$5.61
Large 2	17,118	$4.71	$3.63	$4.56
Broilers				
SO Region				
Medium 1a	36,634	$0.15	$0.10	$0.08
Medium 1b	51,362	$0.14	$0.09	$0.07
Medium 2	73,776	$0.13	$0.08	$0.07
Large 1	117,581	$0.13	$0.08	$0.06
Large 2	281,453	$0.11	$0.06	$0.05
MA Region				
Medium 1a	36,796	$0.13	$0.11	$0.08
Medium 1b	51,590	$0.13	$0.10	$0.07
Medium 2	73,590	$0.12	$0.10	$0.07
Large 1	115,281	$0.12	$0.09	$0.07
Large 2	303,155	$0.10	$0.07	$0.05
Layers				
Wet SO Region				
Small	1,000	$0.83	NA	NA
Medium 2	3,654	$0.55	$0.60	$0.39
Large 1	86,898	$0.27	$0.27	$0.15
Dry SO Region				
Medium 1a	32,375	$0.18	$0.04	$0.02
Medium 1b	44,909	$0.14	$0.04	$0.02
Medium 2	97,413	$0.15	$0.03	$0.02
Large 1	293,512	$0.18	$0.02	$0.02
Large 2	884,291	$0.00	$0.02	$0.02
Dry MW Region				
Medium 1a	37,906	$0.25	$0.05	$0.02
Medium 1b	52,582	$0.27	$0.04	$0.02
Medium 2	97,484	$0.23	$0.04	$0.02
Large 1	279,202	$0.19	$0.03	$0.02
Large 2	1,229,095	$0.00	$0.02	$0.02
Turkeys				
MA Region				
Medium 1a	18,539	$0.71	$0.29	$0.09
Medium 1b	31,267	$0.70	$0.23	$0.07
Medium 2	45,193	$0.61	$0.18	$0.06
Large 1	97,111	$0.57	$0.16	$0.05
MW Region				
Medium 1a	18,092	$0.83	$0.28	$0.13
Medium 1b	30,514	$0.79	$0.22	$0.12
Medium 2	45,469	$0.65	$0.18	$0.10
Large 1	158,365	$0.65	$0.15	$0.10

(a) Two categories of hog farms are included: grower-finish (GF) and farrow-finish (FF).

Table A-10
Total Annualized Compliance Costs per Head for Option 6

Sector/Model	Head	Category 1	Category 2	Category 3
Beef				
MW Region				
Small	112	$17.86	NA	NA
Medium 1	455	$18.34	$21.56	$5.17
Medium 2	777	$11.96	$14.54	$2.56
Large 1	1,877	$1.61	$8.80	$0.60
Large 2	30,003	$0.93	$4.12	$0.16
CE Region				
Medium 1	455	$25.63	$35.32	$5.11
Medium 2	777	$19.21	$26.55	$2.51
Large 1	1,877	$6.44	$14.97	$0.52
Large 2	30,003	$2.94	$10.48	$0.08
Dairy				
PA Region				
Medium 1	235	$21.42	$31.27	$13.76
Medium 2	460	$32.21	$51.40	$26.41
Large 1	1,419	$7.05	$30.15	$3.98
MW Region				
Small	200	$24.58	NA	NA
Medium 1	235	$17.97	$24.85	$10.60
Medium 2	460	$30.74	$44.37	$25.20
Large 1	1,419	$7.62	$21.08	$4.68
Veal				
MW Region				
Medium 1	400	$7.20	$2.76	$2.50
Medium 2	540	$3.72	$2.03	$1.84
Heifers				
PA Region				
Medium 1	400	$17.55	$20.87	$5.67
Medium 2	750	$11.61	$13.85	$3.28
Large 1	1,500	$2.45	$5.03	$0.75
MW Region				
Medium 1	400	$14.98	$17.83	$5.60
Medium 2	750	$9.64	$11.13	$3.23
Large 1	1,500	$1.21	$2.23	$0.67

Table A-10 (continued)
Total Annualized Compliance Costs per Head for Option 6

Sector/Model	Head	Category 1	Category 2	Category 3
Hogs (a)				
MW Region (GF)				
Medium 1a	900	$2.89	$3.52	$7.47
Medium 1b	1,422	$2.67	$6.78	$7.00
Medium 2	2,124	$2.15	$4.48	$5.90
Large 1	3,417	$1.94	$5.33	$6.20
Large 2	10,029	$1.36	$4.27	$5.15
MA Region (GF)				
Medium 1a	963	$3.09	$7.85	$7.34
Medium 1b	1,521	$2.89	$5.86	$7.21
Medium 2	2,184	$2.83	$7.07	$6.87
Large 1	3,554	$2.06	$6.78	$6.18
Large 2	8,893	$2.68	$6.50	$6.41
MW Region (FF)				
Small	750	$0.99	NA	NA
Medium 1a	814	$2.95	$3.87	$6.96
Medium 1b	1,460	$2.65	$4.74	$6.37
Medium 2	2,152	$2.15	$2.18	$5.35
Large 1	3,444	$1.93	$2.65	$5.61
Large 2	13,819	$4.10	$7.00	$7.15
MA Region (FF)				
Medium 1a	846	$3.15	$3.30	$6.92
Medium 1b	1,518	$2.93	$6.70	$6.33
Medium 2	2,165	$2.84	$7.03	$6.17
Large 1	3,509	$2.06	$6.13	$5.61
Large 2	17,118	$3.55	$5.58	$6.48
Broilers				
SO Region				
Medium 1a	36,634	$0.15	$0.10	$0.08
Medium 1b	51,362	$0.14	$0.09	$0.07
Medium 2	73,776	$0.13	$0.08	$0.07
Large 1	117,581	$0.13	$0.08	$0.06
Large 2	281,453	$0.11	$0.06	$0.05
MA Region				
Medium 1a	36,796	$0.13	$0.11	$0.08
Medium 1b	51,590	$0.13	$0.10	$0.07
Medium 2	73,590	$0.12	$0.10	$0.07
Large 1	115,281	$0.12	$0.09	$0.07
Large 2	303,155	$0.10	$0.07	$0.05
Layers				
Wet SO Region				
Small	1,000	$0.32	NA	NA
Medium 2	3,654	$0.24	$0.60	$0.39
Large 1	86,898	$0.15	$0.27	$0.15
Dry SO Region				
Medium 1a	32,375	$0.18	$0.04	$0.02
Medium 1b	44,909	$0.14	$0.04	$0.02
Medium 2	97,413	$0.15	$0.03	$0.02
Large 1	293,512	$0.18	$0.02	$0.02
Large 2	884,291	$0.00	$0.02	$0.02
Dry MW Region				
Medium 1a	37,906	$0.25	$0.05	$0.02
Medium 1b	52,582	$0.27	$0.04	$0.02
Medium 2	97,484	$0.23	$0.04	$0.02
Large 1	279,202	$0.19	$0.03	$0.02
Large 2	1,229,095	$0.00	$0.02	$0.02
Turkeys				
MA Region				
Medium 1a	18,539	$0.71	$0.29	$0.09
Medium 1b	31,267	$0.70	$0.23	$0.07
Medium 2	45,193	$0.61	$0.18	$0.06
Large 1	97,111	$0.57	$0.16	$0.05
MW Region				
Medium 1a	18,092	$0.83	$0.28	$0.13
Medium 1b	30,514	$0.79	$0.22	$0.12
Medium 2	45,469	$0.65	$0.18	$0.10
Large 1	158,365	$0.65	$0.15	$0.10

(a) Two categories of hog farms are included: grower-finish (GF) and farrow-finish (FF).

Table A-11
Total Annualized Compliance Costs per Head for Option 7

Sector/Model	Head	Category 1	Category 2	Category 3
Beef				
MW Region				
Small	112	$18.21	NA	NA
Medium 1	455	$18.34	$21.56	$5.17
Medium 2	777	$13.18	$15.76	$3.79
Large 1	1,877	$2.42	$9.61	$1.41
Large 2	30,003	$1.19	$4.38	$0.42
CE Region				
Medium 1	455	$25.63	$35.32	$5.11
Medium 2	777	$21.39	$28.73	$4.69
Large 1	1,877	$7.87	$16.40	$1.95
Large 2	30,003	$3.43	$10.98	$0.57
Dairy				
PA Region				
Medium 1	235	$21.42	$27.81	$13.76
Medium 2	460	$34.26	$50.30	$28.45
Large 1	1,419	$24.69	$45.88	$21.62
MW Region				
Small	200	$13.14	NA	NA
Medium 1	235	$17.97	$21.60	$10.60
Medium 2	460	$37.31	$47.79	$31.77
Large 1	1,419	$27.62	$39.13	$24.68
Veal				
MW Region				
Medium 1	400	$7.20	$2.76	$2.50
Medium 2	540	$3.72	$2.03	$1.84
Heifers				
PA Region				
Medium 1	400	$17.55	$21.92	$5.67
Medium 2	750	$11.61	$14.38	$3.28
Large 1	1,500	$2.45	$5.03	$0.75
MW Region				
Medium 1	400	$14.98	$17.83	$5.60
Medium 2	750	$9.64	$11.13	$3.23
Large 1	1,500	$1.21	$2.23	$0.67

Table A-11 (continued)
Total Annualized Compliance Costs per Head for Option 7

Sector/Model	Head	Category 1	Category 2	Category 3
Hogs (a)				
MW Region (GF)				
Medium 1a	900	$2.89	$8.79	$7.47
Medium 1b	1,422	$2.67	$10.68	$7.00
Medium 2	2,124	$2.15	$7.08	$5.90
Large 1	3,417	$1.94	$7.52	$6.20
Large 2	10,029	$1.69	$5.80	$5.48
MA Region (GF)				
Medium 1a	963	$3.09	$13.00	$7.34
Medium 1b	1,521	$2.89	$9.68	$7.21
Medium 2	2,184	$2.83	$10.15	$6.87
Large 1	3,554	$2.06	$8.92	$6.18
Large 2	8,893	$1.79	$6.87	$5.52
MW Region (FF)				
Small	750	$2.28	NA	NA
Medium 1a	814	$2.95	$9.52	$6.96
Medium 1b	1,460	$2.65	$8.58	$6.37
Medium 2	2,152	$2.15	$4.77	$5.35
Large 1	3,444	$1.93	$4.83	$5.61
Large 2	13,819	$1.53	$5.41	$4.58
MA Region (FF)				
Medium 1a	846	$3.15	$8.93	$6.92
Medium 1b	1,518	$2.93	$10.53	$6.33
Medium 2	2,165	$2.84	$10.12	$6.17
Large 1	3,509	$2.06	$8.29	$5.61
Large 2	17,118	$1.62	$4.56	$4.56
Broilers				
SO Region				
Medium 1a	36,634	$0.15	$0.10	$0.08
Medium 1b	51,362	$0.14	$0.09	$0.07
Medium 2	73,776	$0.13	$0.08	$0.07
Large 1	117,581	$0.13	$0.08	$0.06
Large 2	281,453	$0.11	$0.06	$0.05
MA Region				
Medium 1a	36,796	$0.13	$0.11	$0.08
Medium 1b	51,590	$0.13	$0.10	$0.07
Medium 2	73,590	$0.12	$0.10	$0.07
Large 1	115,281	$0.12	$0.09	$0.07
Large 2	303,155	$0.10	$0.07	$0.05
Layers				
Wet SO Region				
Small	1,000	$0.32	NA	NA
Medium 2	3,654	$0.24	$0.60	$0.39
Large 1	86,898	$0.15	$0.27	$0.15
Dry SO Region				
Medium 1a	32,375	$0.18	$0.04	$0.02
Medium 1b	44,909	$0.14	$0.04	$0.02
Medium 2	97,413	$0.15	$0.03	$0.02
Large 1	293,512	$0.18	$0.02	$0.02
Large 2	884,291	$0.00	$0.02	$0.02
Dry MW Region				
Medium 1a	37,906	$0.25	$0.05	$0.02
Medium 1b	52,582	$0.27	$0.04	$0.02
Medium 2	97,484	$0.23	$0.04	$0.02
Large 1	279,202	$0.19	$0.03	$0.02
Large 2	1,229,095	$0.00	$0.02	$0.02
Turkeys				
MA Region				
Medium 1a	18,539	$0.71	$0.29	$0.09
Medium 1b	31,267	$0.70	$0.23	$0.07
Medium 2	45,193	$0.61	$0.18	$0.06
Large 1	97,111	$0.57	$0.16	$0.05
MW Region				
Medium 1a	18,092	$0.83	$0.28	$0.13
Medium 1b	30,514	$0.79	$0.22	$0.12
Medium 2	45,469	$0.65	$0.18	$0.10
Large 1	158,365	$0.65	$0.15	$0.10

(a) Two categories of hog farms are included: grower-finish (GF) and farrow-finish (FF).

APPENDIX B

MARKET MODEL DESCRIPTION

This appendix describes the market model that EPA uses to estimate changes in market prices and quantities attributable to the proposed CAFO regulations. Section B.1 presents a non-technical overview of the market model. Section B.2 describes the selection of baseline parameters and elasticities for the model. Section B.3 presents the model in more technical detail and is intended for readers with a background in microeconomics. Section B.4 discusses how the model is used to estimate the impacts of regulatory costs. Section B.5 contains a glossary of notation for the COSTBEN and EPA market models.

B.1 INTRODUCTION AND OVERVIEW

The market model for this analysis is adapted from the COSTBEN model developed by the U.S. Department of Agriculture, Economic Research Service (ERS) to analyze the effects of policy changes on livestock and poultry markets (Hahn, 1996). COSTBEN uses a linear, partial equilibrium model of supply and demand for a product with two stages of production: a market for the final product, e.g., retail beef products, and a market for the intermediate product, e.g., fed cattle. The model is typical of textbook supply and demand analysis (Tomek and Robinson, 1972; Kohls and Uhl, 1998). The model assumes perfect competition in all markets. Supply and demand "curves" are assumed to be straight lines (i.e., linear model).

The EPA market model differs from COSTBEN in several ways. COSTBEN forecasts the short-run dynamics of the market as it evolves to a new long-run equilibrium using an iterative process, in which the model is recalibrated to a forecast baseline at each iteration. A long-run static analysis is more appropriate for analysis of the ultimate market effects of the proposed CAFO regulations. EPA's market model is simpler than COSTBEN because it extracts only those elements of the COSTBEN model essential to finding a long-run equilibrium. COSTBEN includes models for more general categories of poultry and red meat, and sector-specific models for cattle, hogs, chicken, and turkeys sold for slaughter. EPA expands on the COSTBEN data sets to include separate models for each sector, including cattle, hogs, broilers, and turkeys, as well as the non-meat sectors (egg layers and milk cows). For the egg and dairy sectors, the intermediate product/final product model structure reflects the market conditions for eggs and milk.

The EPA market model, like COSTBEN, treats each animal sector separately. Each sector has two markets: the market for the intermediate products of farm production, cattle, hogs, broilers, turkeys, raw milk, and eggs (henceforth termed collectively as "farm products") and the retail market for their related finished products (poultry and red meats, fluid milk and dairy products, and shell eggs). The markets are related since the supply of farm products affects the supply of retail products and the demand for finished goods generates a derived demand for farm products. The model, basically, puts the supply of each farm product into the same units as demand for the related retail product and finds the price and quantity where supply equals demand. This is the long-run equilibrium point. Regulatory costs are modeled as shifts in the demand or supply functions. The proposed CAFO regulations increase producers' costs so they are modeled as an upward shift in the supply function. EPA measures these impacts as the change from the baseline equilibrium to the new post-regulatory equilibrium.

The EPA market model can be thought of as starting with the domestic farm product supply function. For any price, this function tells how much product will be raised for sale by U.S. farmers. Additional supplies of imported farm products are added to domestic supply, and exports are subtracted to yield a trade-adjusted supply function for the farm product. The trade-adjusted supply function is a modeling convenience which summarizes in one equation all of the farm product available to U.S. processors.[1] In the poultry and dairy markets, where there is no significant international trade in the raw farm products, the trade-adjusted supply function is identical to the domestic supply function. While international trade in cattle and hogs is not a large factor in the U.S. market, free trade agreements with Canada and Mexico have resulted in importation of fed cattle and hogs for slaughter by U.S. packers.

Raw farm products are processed into finished products. The EPA market model describes the processing step with a conversion ratio and marginal processing cost. The conversion ratio expresses the amount of farm output required to make the finished product. For example, in the beef model it converts number of cattle slaughtered to pounds of beef produced. The marginal processing cost per animal shows the processing industry's costs of production. In the EPA market model, marginal costs of processing are just the difference between the retail price and the farm level price adjusted so they are in the same units. The marginal processing cost includes transportation to market and retail packaging, as well as those activities typically associated with packing and processing animal products. The trade-adjusted supply function for farm output can be converted to a supply function for finished, retail products using the conversion ratio and marginal processing cost.

To find the long-run equilibrium, supply must equal demand. The model has a linear domestic demand function for the retail product. In addition to domestic production, retail products are imported and exported. Supply and demand conditions in these markets are discussed in detail in Section 2.2.3. The domestic retail demand is adjusted by retail product imports and exports to yield a trade-adjusted demand function for the retail product. As the trade-adjusted supply function is a convenient summary of inputs available to domestic processors, so trade-adjusted demand is a convenient summary of distribution of their products. The trade-adjusted retail supply function is equated to the trade-adjusted retail demand function to find the long-run equilibrium price and quantity in the retail product market.

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[1]Trade-adjusted supply differs from "Total Supply," which is domestic production plus imports, in that it includes exports. Trade-adjusted supply also differs from "Net Trade" in that it includes domestic production.

Once the long-run equilibrium retail price is determined, the conversion ratio and the marginal processing cost relationships allow EPA to translate the retail price to a price for the farm product. The farm product price applied to the farm product supply function determines the quantity that will be produced domestically at the market equilibrium. The retail and farm product prices also determine the quantities of imports and exports of the farm and retail products when applied to the import and export equations.

The EPA market model deals with each of six animal sectors individually. The model does not account for possible multi-market effects and interactions between one sector and the other livestock and poultry sectors or other sectors in the economy. (The general equilibrium price effects are discussed in more detail in Section B.3.) The model also does not account for the possibility that consumers may substitute red meat for chicken (when chicken prices rise, for example). Studies have shown that interventions in one market may have effects in other markets (Thurman and Wohlgenant, 1989).

Like COSTBEN, the EPA market model is used to evaluate alternatives by changing some assumptions or parameters of the model. For analysis of the proposed CAFO regulations, the compliance costs increase farmers' marginal costs of production. EPA estimates the impact of the regulation by how that shift affects the overall market. Changes in prices and welfare are measured as differences between the baseline, preregulatory equilibrium and the shocked, postregulatory equilibrium. Figure B-1 summarizes the baseline and postregulatory states of the model (subscripted as b and 1 respectively).[2] Higher farm costs shift the domestic farm product supply function to the left, which similarly shifts the finished product supply function and the equilibrium price at the intersection of retail supply and demand rises. There is considerable evidence in the literature that shocks to farm level prices are quickly transmitted to retail markets (McIntosh, Park, and Karnum, 1997; Goodwin and Holt, 1999). Higher retail prices imply higher farm product prices and lower farm product sales. A summary of the empirical research on the ability of producers to pass on compliance costs is provided in the rulemaking record (ERG, 2000c)**.**

These changes in prices and quantities directly affect the revenue, costs, production, and employment of firms throughout the marketing chain. (These relationships are also discussed in Section 4.4.1 of this report). Farms must pay for improvements to comply with the new regulations as well as sell a smaller quantity because of the increase in price. The shaded area in the Domestic Farm Product Market panel of Figure B-2 illustrates the direct impact on farms. The processing industry also feels the effects of smaller production. Consumers absorb some of the compliance costs through the cost passthrough process. These direct impacts are shown by the shaded areas in the Retail Product Market panel of Figure B-2. These direct effects have

[2]Figures are included in this section for illustration and will be discussed in more depth in Sections B.3 and B.4. Variables are defined in Section B.3 and appear in a glossary in Section B.5.

Figure B-1 Livestock and Poultry Products Market Model

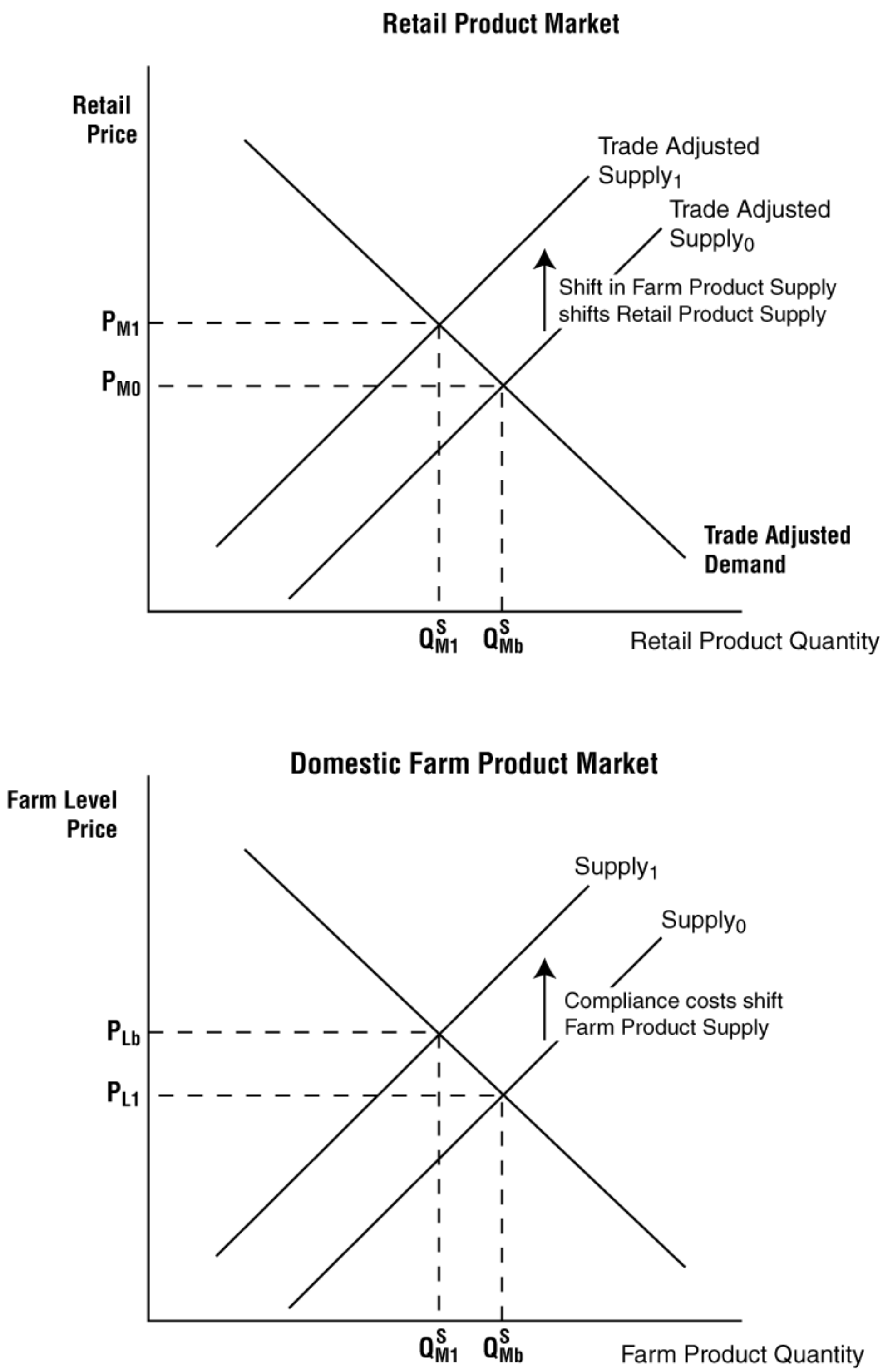
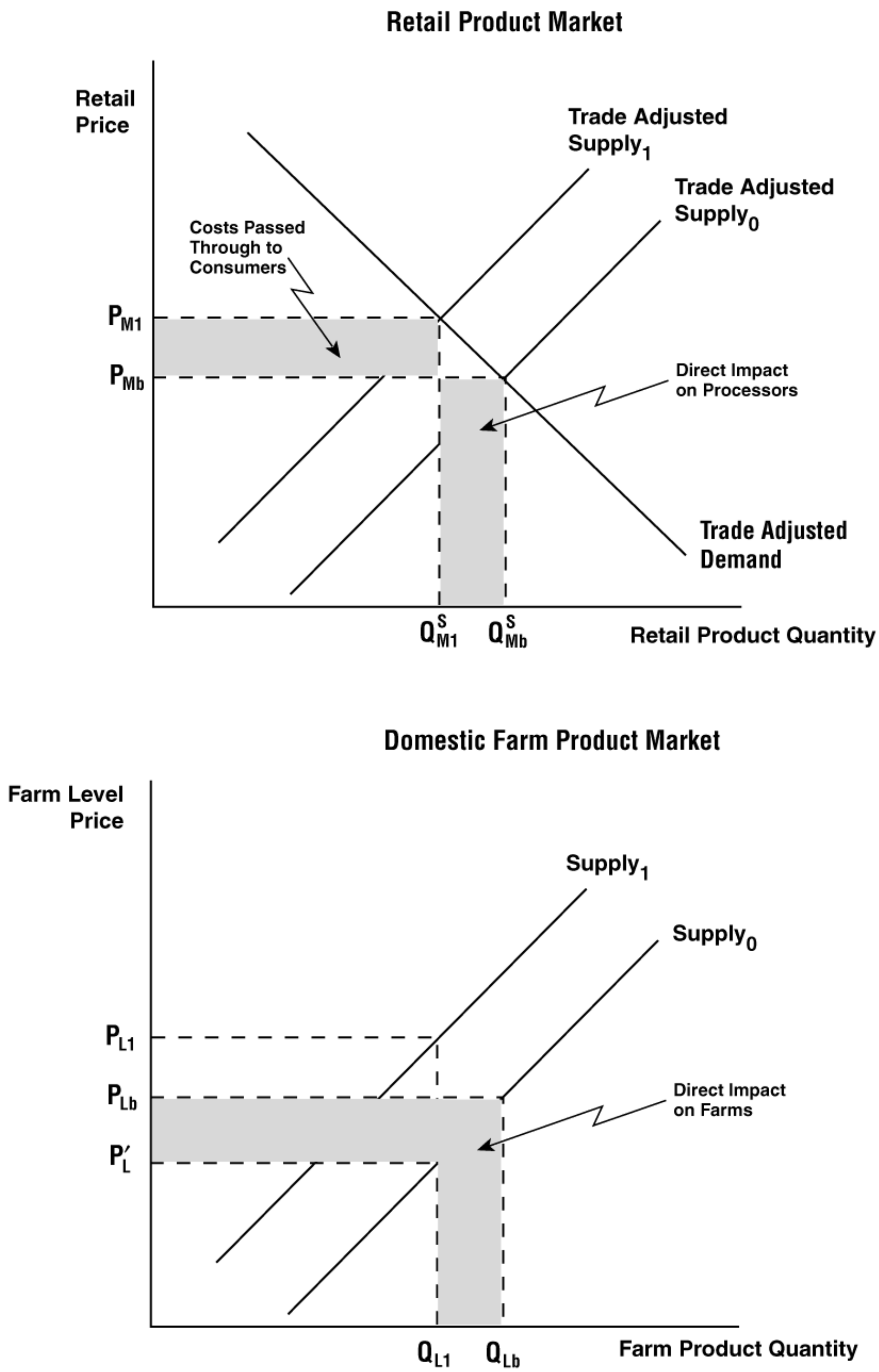


Figure B-2. Direct Impacts



ripple effects throughout the economy. The EPA market model calculates the changes in quantities supplied and demanded for each commodity at the farm, processor, and consumer levels. Using the estimated market value of these quantity changes, EPA is able to evaluate other direct and indirect effects, including changes in national employment and changes in national economic flows throughout the economy.

B.2 MODEL PARAMETERS AND DATA

Section 4.4.2 of this report discusses the sources used for data and parameters in the EPA market model. This section discusses the selection of elasticities and baseline values for the model. COSTBEN and the EPA market model require specification of six long-run elasticity estimates: farm product supply, farm product import supply, farm product export demand, retail import supply, retail export demand, and domestic retail product demand. These elasticities determine the slopes of the model functions and thus show how much quantities change when prices change. To establish the starting conditions for the model, a base year is selected. All of the coefficients of the model are derived so that the undisturbed model yields the baseline results.

EPA has conducted an extensive literature review to find elasticity values for relevant markets from existing agricultural economic studies. This literature review is summarized in Appendix C of this report. Although there are many studies, there is little consensus on the correct demand and supply elasticities for the relevant markets. Table B-1 summarizes the results of the literature search with the maximums and minimums observed. Differences among estimates depend on many factors. Many different econometric methods are used in these studies. Additionally, the studies encompass differing production time frames and sample years.

EPA uses the price elasticity of demand values reported by USDA from an integrated analysis of retail demand for food (Huang, 1993). The use of results from a single study ensures consistency of methods and sample. Table B-1 shows that the values Huang found are comparable to other demand elasticities in the literature. In general, food demand tends to be inelastic because food is a necessity. For some products, such as beef, sales are more sensitive to price because many beef products are considered luxuries and have many substitutes. Milk and eggs are staples in many peoples' diets and have few substitutes, so demand is very inelastic, i.e., quantities do not change much in response to changes in price. Retail demand elasticities are appropriate for the COSTBEN and EPA market models which convert farm product supply into retail market terms.

The available estimates of price elasticities of supply are not estimated in a similar unified way because each sector has different characteristics. For this analysis, EPA uses supply elasticities for the model that originate from various different sources. In some cases, both short- and long-run price elasticity of supply estimates are available. Short-run price elasticities of

Table B-1. Elasticity Estimates in the Agricultural Economics Literature [a/]

Variable	Beef [b/]	Dairy	Hog	Broiler [c/]	Layer	Turkey
Price Elasticity of Demand						
Maximum	-0.45	-0.05	-0.07	-0.10	-0.02	-0.37
Minimum	-1.27	-0.65	-1.23	-1.25	-0.78	-0.68
Selected (Huang, 1993)	-0.621	-0.247	-0.728	-0.372	-0.110	-0.535
Price Elasticity of Supply						
Maximum	3.24	6.69	1.80	0.59	0.94	0.52
Minimum	0.06	0.07	0.01	0.06	0.03	0.21
Selected [d/]	1.020	1.527	0.628	0.20	0.942	0.20

[a/]See Appendix C for maximum and minimum citations.
[b/]Excludes ground beef.
[c/]Includes various forms of chicken meat.
[d/]Selected elasticity of supply sources: Beef, including heifers and veal (Foster and Burt, 1992, adjusted by Foster, 2000a); Dairy (Chavas, Kraus, and Jesse, 1990); Hog (Holt and Johnson, 1988); Broiler and Turkey (Vukina, 2000); Layer (Chavas and Johnson, 1981).

supply tend to be inelastic because the flow of animal products to market is determined by decisions made several months, or years, before the products will reach the market. In contrast, some livestock economic models assume that long-run elasticities of supply are perfectly elastic because producers have time to adjust their production decisions and adapt to changing conditions (Hahn, 1998). The biology of the animal production process limits the adaptability of producers to changing market conditions. The “long run” is longer for animals with slow production cycles than for those with relatively fast cycles. Chicken flock size, for example, can be adjusted within a few months, while cattle herds require years to adjust. As this is a long-run analysis, EPA has generally selected more elastic price elasticity of supply values from the range in the literature.

EPA did not identify estimates of the elasticity of imports and exports for these sectors from the available literature. Many factors affect imports and exports including exchange rates, foreign economic conditions, weather in competing production areas, and foreign government policies. For simplicity, COSTBEN and the EPA market model summarize all of these factors into linear supply and demand functions that represent the rest of the world. Although there is a general consensus that foreign markets are more sensitive to prices than domestic markets (Foster, 2000a), rest-of-the-world response to changes in U.S. prices for animal products has not been widely studied. EPA assumes that elasticities for imports are the same as domestic supply elasticities, and export demand elasticities are the same as domestic demand elasticities.

To assess how the elasticity choices affect the market model results, EPA conducted sensitivity analyses using the minimum and maximum elasticities as well as changing the trade assumptions. These sensitivity analysis results appear in Appendix D of this report. These sensitivity analyses conclude that the results presented in Section 5 of this report are stable across a range of possible modeling assumptions.

To scale the model to observed values, a base year must be selected. The model coefficients are calculated so that the baseline values are an equilibrium point in both the farm product and retail markets. Any year with adequate data could serve as a base year. EPA selected 1997 to correspond with the year of the engineering cost and financial data. Sensitivity analyses in Appendix D indicate that the selection of baseline prices has little effect on model outcomes given the size of shocks being evaluated. The baseline values and sources for all variables, i.e., prices and quantities, and parameters, i.e., elasticities and multipliers, are summarized in Section 4.4.2 and Table 4-14 of this report.

B.3 MODEL IN DETAIL

The framework of EPA's market model is based on USDA's COSTBEN model. This section discusses the economic assumptions underlying the two models and highlights the differences between them. COSTBEN is a highly simplified, partial equilibrium model intended for "quick turn-around analysis of policy changes and other shocks to a single species' livestock and meat market" (Hahn, 1996). To maintain its simple structure, much of the detail of animal products markets is assumed away. For example, all imported, exported, and produced livestock are assumed to be the same. Imports, exports, and domestic production all have the same price because of this assumption. Each retail product, e.g. beef, is also assumed to be uniform and therefore have the same price. The problems of making pounds of filet mignon exported equivalent to pounds of ground beef imported is avoided by assuming all beef is the same. Each sector has similar equivalency issues which are handled by calibrating the retail quantities to USDA's product disappearance tables (Putnam and Allshouse, 1999).

A shortcoming of COSTBEN and the EPA market model is their failure to account for general equilibrium effects of incremental compliance costs. All of the animal sectors interact in both supply and demand. Animal sectors compete for feed, for example, such that increased demand in one sector may drive up feed prices in other sectors. Milk and egg producers that principally raise animals for non-meat production may at times cull their herd or flock and sell animals to meat markets. Many of the retail products are substitutes for each other, so price changes in one sector will affect demand in others. This partial market abstraction can only be justified if the expected shocks are so small that the general equilibrium effects would be negligible.

COSTBEN and the EPA market model are designed to analyze competitive markets in which an intermediate product makes up a large proportion of the value of the finished product.

This may be a fair characterization of the cattle industry and much of hog production. Poultry, however, is produced by large integrators who sell to a small number of distributors and grocery chains, i.e., a bilateral oligopoly with fully integrated production. Dairy markets are dominated by farmer cooperatives and retail chains, i.e., a bilateral oligopoly. COSTBEN and the EPA market model are not sophisticated enough to capture any of the game theoretic workings of oligopolistic markets. A model including these aspects of the market would require assumptions about many more parameters. The values of these parameters have not been established in the empirical literature. While these are significant deficiencies, the general directions of changes in prices and quantities do not change because of these market structure issues.

In highly integrated production processes, such as broilers and turkeys, the farm price reported by USDA is an internal transfer price imputed from the retail price and other information. The amount farmers receive per pound for contract production is considerably less. As the actual contract payments are not public information, they could not be used in the EPA market model. Thus, poultry impacts and production changes are in the context of USDA prices which may be considerably different from the situation for contract growers.

The model for each animal sector has eleven equations.[3] Table B-2 summarizes the model equations. Up to three equations model the farm product supply sector. One equation accounts for domestic production in each animal sector. In the cattle and hog sectors, two equations also model animal imports and exports. A fourth equation combines these together into the trade-adjusted retail product supply function. Similarly, three equations model the retail product market, accounting for domestic retail product demand, foreign imports, and exports. A fourth equation combines these together into the trade-adjusted retail product demand function. A single equation models the processing sector. A final equation closes the model by finding the long-run market equilibrium price of the retail product. All of the relationships within the model are linear of the form Q=A+BP; thus all of the equilibria are unique and stable. The notation for the model is summarized in a glossary at the end of this appendix. The glossary shows each symbol, its definition, and the numbers of the equations in which it is used.

B.3.1 Farm Production Sector

This section describes the four equations that define the supply of farm product available for processing, which include: the farm product imports equation (Section B.3.1.1); the farm product exports equation (Section B.3.1.2); the domestic farm product supply equation (Section B.3.1.3); and the trade-adjusted farm product supply equation (Section B.3.1.4).

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[3]Of these equations: (1) two equations are summary equations that combine equations to determine trade-adjusted supply and demand; and (2) two equations are identities that close the model by finding the long-run market equilibrium price of the retail product.

Table B-2. General Structure of the Model

Equation	Name
Farm Production Sector	
1	Farm Product Imports Equation
2	Farm Product Exports Equation
3	Domestic Farm Product Supply Equation
4 (summary)	Trade-Adjusted Farm Product Supply Equation, combines 1-3
Processing Services Sector	
5	Definition of Conversion Ratio
6	Marginal Costs of Processing
Retail Product Sector	
7	Retail Product Import Equation
8	Retail Product Export Equation
9	Domestic Retail Product Demand Equation
10 (summary)	Trade-Adjusted Retail Product Demand Equation, combines 7-9
13	Price of Retail Product at Market Equilibrium, equates 4 and 10

B.3.1.1 Farm Product Imports Equation

Cattle and hogs are imported into the U.S. for slaughter. This equation and the analogous export equation are not used in the other sector models. Imports of these farm products are considered a function of the U.S. price, P_L[4]:

$$Q_L^I = \alpha_1 + \beta_1 P_L \qquad \textbf{(1)}$$

where the intercept, α_1, and the price coefficient, β_1, are calculated from the specified elasticities and baseline market conditions. The model is of constant slope form. The relationships between

[4]All farm product variables are subscripted L; retail market variables are subscripted, M. This is a holdover from the red meat-oriented COSTBEN model which dealt solely in livestock and meat. The subscript b indicates the value of the variable in the baseline equilibrium. Superscript I indicates imports, X indicates exports, and S indicates a net total of domestic products, imports, and exports.

prices and quantities are specified as elasticities, i.e., $\eta = (\partial Q/\partial P)(P/Q)$. Elasticities must be converted to slopes, $\beta = \partial Q/\partial P$, to define the model's functions. At the baseline equilibrium price and quantity, $\beta = \eta(Q/P)$. The intercept, α, is found by inserting β and the baseline values for Q and P into equation 1 and solving for α. A similar process is followed to calibrate all of the coefficients:

$$
\begin{aligned}
Q_L^I &= \text{Quantity of farm product imported} \\
P_L &= \text{Price of farm product} \\
\alpha_1 &= \text{Intercept of farm product import supply} \\
&= Q_{L,b}^I - \beta_1 P_{L,b} \\
\beta_1 &= \text{Coefficient on } P_L \text{ of farm product import supply} \\
&= LMSE * \frac{Q_{L,b}^I}{P_{L,b}} \\
&= LMSE * \frac{\text{baseline imported product quantity}}{\text{baseline farm price}} \\
LMSE &= \text{Import supply elasticity of farm product}
\end{aligned}
$$

B.3.1.2 Farm Product Exports Equation

Cattle and hog exports are also a function of current U.S. price:

$$Q_L^X = \alpha_2 + \beta_2 P_L \tag{2}$$

where Q_L^X is the quantity of farm products exported and the coefficients are calibrated as in equation 1.

B.3.1.3 Domestic Farm Product Supply Equation

In the short-run COSTBEN model, domestic farm product supply converges to the long-run equilibrium by means of a lagged output coefficient. In repeated solutions of the model, the lagged prices and quantities move the solution gradually toward the long-run equilibrium as prices and quantities adapt. In the EPA long-run model, the lagged variables are irrelevant because the markets have reached a stable equilibrium such that lagged variables equal current variables, i.e., $P_t = P_{t-1}$ and $Q_t = Q_{t-1}$. The long-run domestic farm product supply is simply:

$$Q_L = \alpha_3 + \beta_3 P_L \tag{3}$$

where Q_L is domestic production of the farm product and the coefficients are calculated from baseline data and parameters in the same way as in equation 1.

B.3.1.4 Trade-Adjusted Farm Product Supply Equation

For convenience, it is useful to combine the farm product export, import, and domestic supply equations into a single, long-run, trade-adjusted farm product supply equation by summing the farm production and import equations (equations 3 and 1), and subtracting the farm product exports equation, (equation 2). The result is equation 4:

$$Q_L^S = \alpha_0 + \beta_0 P_L \tag{4}$$

where:

$$\begin{aligned}
Q_L^S &= \text{Quantity of farm product available for processing} \\
\alpha_0 &= \text{Intercept of trade-adjusted farm product supply equation} \\
&= \alpha_1 - \alpha_2 + \alpha_3 \\
\beta_0 &= \text{Coefficient on } P_L \text{ of trade-adjusted farm product supply equation} \\
&= \beta_1 - \beta_2 + \beta_3
\end{aligned}$$

B.3.2 The Processing Sector

The processing industry uses labor, capital, and other inputs to convert farm products into a finished retail product. COSTBEN and the EPA market model similarly convert farm product prices and quantities into retail product prices and quantities. The conversion ratio (Conv) is the baseline quantity of retail product produced divided by the baseline amount of farm product introduced to the process:

$$\mathrm{Conv} = \frac{Q^{S}_{M,b}}{Q^{S}_{L,b}} \tag{5}$$

The conversion ratio expresses the amount of farm product needed to make a unit of finished product and changes the units of measure from farm level units, such as number of animals or hundredweight of milk, in the farm product market to pounds of retail product.

The processor also adds value to the product using labor and capital. Thus, the price of the retail product is higher than the price of the farm product by the processor's marginal costs. The EPA market model differs slightly from COSTBEN in its treatment of processors' costs. COSTBEN assumes marginal costs increase linearly by a factor of δ_1 as the quantity of retail product processed increases. This assumption avoids the need to include the costs of other processing inputs in the model and may be defensible, since farm products are a large proportion of processors' costs. In COSTBEN, the price of the farm level output is equal to the price of the retail product less the marginal cost of processing times the conversion ratio:

$$P_L = \mathrm{Conv} * (P_M - (\phi_1 + \delta_1 * Q^{S}_{M})) \tag{6a}$$

where:

$$P_M = \text{Price of retail product}$$

$$Q^{S}_{M} = \text{Quantity of net retail product demand}$$

$$\mathrm{Conv} = \text{Conversion ratio} = \frac{\text{baseline retail product quantity}}{\text{baseline farm product quantity}}$$

ϕ_1 = Intercept of marginal cost of processing services equation

$$= P_{M,b} - \frac{P_{L,b}}{Conv}$$

δ_1 = Coefficient on Q_M^S of marginal cost of processing services equation

Measurement of the rate of change of processors' costs is difficult, so reliable estimates of δ_1 are not available. The EPA market model carries COSTBEN's simplification further by assuming the marginal costs of processing are constant in the long run and estimating them from the baseline data as ϕ_1. With the assumption of constant processors' marginal costs in the EPA market model, the processing services equation becomes:

$$P_L = Conv * (P_M - \phi_1) \tag{6}$$

B.3.3 Retail Product Sector

This section describes the four model equations that characterize the retail product market, which include: the retail product import equation (Section B.3.3.1); the retail product export equation (Section B.3.3.2); the domestic retail product demand equation (Section B.3.3.3); and the trade-adjusted retail product demand equation (Section B.3.3.4).

B.3.3.1 Retail Product Import Equation

The retail product import equation is:

$$Q_M^I = \sigma_1 + \gamma_1 P_M \tag{7}$$

where:

$$Q_M^I = \text{Quantity of retail products imported}$$

$$\sigma_1 = \text{Intercept of retail product import supply equation}$$

$$= Q_{M,b}^I - \gamma_1 P_{M,b}$$

$$\gamma_1 = \text{Coefficient on } P_M \text{ of retail product import supply equation}$$

$$= \text{MMSE} * \frac{Q_{M,b}^I}{P_{M,b}}$$

$$\text{MMSE} = \text{Elasticity of retail product import supply}$$

B.3.3.2 Retail Product Export Equation

The retail product export demand equation is:

$$Q_M^X = \sigma_2 + \gamma_2 P_M \qquad (8)$$

where Q_M^X is the quantity of retail product exported and the coefficients are calibrated similarly to equation 7.

B.3.3.3 Domestic Retail Product Demand Equation

The domestic retail product demand equation is:

$$Q_M = \sigma_3 + \gamma_3 P_M \qquad (9)$$

where Q_M is the quantity of domestic retail product demand and the coefficients are calibrated similarly to equation 7.

B.3.3.4 Trade-adjusted Retail Product Demand Equation

As in the production sector, it is convenient to combine the retail product import, export, and domestic demand equations into a single trade-adjusted retail product demand equation by adding retail product exports and domestic demand (equations 8 and 9), and subtracting retail product imports (equation 7):

$$Q_M^S = \sigma_0 + \gamma_0 P_M \tag{10}$$

where:

Q_M^S = Quantity of net retail product demand

σ_0 = Intercept of trade−adjusted retail product demand

= $\sigma_3 + \sigma_2 - \sigma_1$

γ_0 = Coefficient on P_M of trade−adjusted retail product demand

= $\gamma_3 + \gamma_2 - \gamma_1$

B.3.4 The Long-Run Market Equilibrium

Algebraically, the first step to solving for the market equilibrium is to put the trade-adjusted farm product supply in terms of the retail product market. To accomplish this, the processing services equation (equation 6) is substituted for P_L in the trade-adjusted farm output supply equation (equation 4). Equation 5 converts the Q_L^S on the left-hand side to Q_M^S. The result is equation 11, which is the farm product supply function converted into retail market terms:

$$\frac{Q_M^S}{\mathrm{Conv}} = \alpha_0 + \beta_0 (\mathrm{Conv}(P_M - \phi_1)) \tag{11}$$

Solving the supply equation 11 for Q_M^S and setting it equal to demand (equation 10) yields:

$$\sigma_0 + \gamma_0 P_M = \mathrm{Conv}(\alpha_0 + \beta_0 \mathrm{Conv}(P_M - \phi_1)) \tag{12}$$

Solving for P_M gives the equilibrium retail price in terms of the coefficients of the model:

$$P_M = \frac{\sigma_0 - \text{Conv}(\alpha_0 + \text{Conv}\,\beta_0\,\phi_1)}{\text{Conv}^2\,\beta_0 - \gamma_0} \tag{13}$$

The analogous retail product price equation in COSTBEN is more complex because it includes the lagged farm output price and quantities and the variable marginal processing costs of the retail product. The lagged variables were part of the short-run adjustment process in the model and are unnecessary in EPA's long-run equilibrium model. As discussed above, the variable marginal costs contribute to the reality of the model by indicating the additional costs of other inputs, but also introduce an additional parameter which is poorly measured. For the small changes considered in this model, the assumption of constant marginal processing costs is of little consequence to the results.

After the retail product price is calculated, the quantity of retail product imported, exported, and consumed domestically can be calculated from their respective equations. The price of the farm product is calculated from the wholesale price of the retail product using the marginal cost of processing services equation, and the quantity of farm output imported, exported, and produced domestically can be calculated from their respective equations.

B.4 USING THE MARKET MODEL

B.4.1 Measuring Changes in Prices and Quantities

In the COSTBEN model, all of the coefficients can be adjusted to reflect changes in policy. The COSTBEN model contains the flexibility to analyze export promotion and import restriction programs as well as shifts in demand and supply. EPA expects that the proposed CAFO regulations will primarily affect domestic farm product supply. The market model evaluates impacts in terms of market responses to a shift in the domestic farm product supply function. Knowing this in advance, the EPA market model can be simplified to accommodate only a single parameter change.

There are several conceivable ways to shift the domestic supply of farm product function in response to the proposed CAFO regulations. The EPA market model takes a constant slope approach while COSTBEN takes a constant elasticity approach. In the COSTBEN model, shocks in domestic supply enter the model as proportional changes in the coefficients of the initial supply function. (The COSTBEN model user must calculate the proportional change in supply attributable to the policy question of interest through some process outside of the model itself.) The COSTBEN postregulatory domestic farm product supply function is:

$$Q_L = (\alpha_3 + \beta_3 P_L) * (1 + \%\ \text{supply shift}) \tag{14}$$

Both the intercept, α_3, and the slope, β_3, of the domestic supply equation change from their preregulatory values by the same proportion. Postregulatory equilibrium prices and quantities are then calculated using this postregulatory domestic farm product supply equation in place of the preregulatory farm product supply equation. The COSTBEN approach to modeling the supply shift ensures that the postregulatory supply function has the same elasticity as the preregulatory supply function, but it will have a different slope.

The EPA market model's focus is a shift in supply caused by regulatory compliance costs. The shift is considered to be the change in price required to supply the initial quantity of farm products and cover the new costs of the proposed regulations, i.e., a parallel upward shift in the supply curve. CAFO regulatory compliance involves both capital improvements and changes in operations. The EPA market model is a long-run, national analysis; all factors of production can be changed, and all costs may be considered continuously variable. Thus CAFO regulatory compliance costs may reasonably be spread over all of the units of production without regard to fixed or variable costs or the "lumpiness" of compliance investments. The supply curve must rise by the average compliance cost per unit of farm product (Shock) to cover the farm costs of the proposed regulation. The shocked intercept, $\alpha_3^{Shocked}$, is calculated as if the price at the preregulatory quantity includes the shock:

$$\alpha_3^{Shocked} = Q_{L,b} - \beta_3 (P_{L,b} + \text{Shock}) \tag{15}$$

where:

$\alpha_3^{Shocked}$ = Postregulatory intercept of domestic farm product supply function

$$\text{Shock} = \frac{\text{annualized national postcompliance costs}}{\text{baseline domestic farm product quantity}}$$

Substituting $\alpha_3^{Shocked}$ in place of α_3 in the domestic farm product supply function yields the shifted (shocked) supply function, Supply_1, in Figure B-2. To find the new postregulatory equilibrium prices and quantities, the EPA market model is solved with $\alpha_3^{Shocked}$ in place of α_3 in the domestic farm product supply function. The model calculates changes in prices and quantities by subtracting their values in the shocked model's equilibrium outcome from their baseline values. These changes are reported in Section 5.4 of this report.

B.4.2 Industry Direct Impacts

One measure of direct impacts is the change in the total value of the products produced by the industry, i.e., industry output. The shift in the supply curve discussed above causes four changes in industry output. At the farm level, compliance costs are absorbed and the quantity sold is reduced. At the retail level, processors' sales are reduced and compliance costs are absorbed by consumers. Each of these impacts is distinct, so they may be added together to show the total direct impact of the proposed regulation.

The shaded area of the Domestic Farm Product Market panel in Figure B-2 illustrates the direct impact of additional compliance costs on farm output. Farm impacts have two components: absorbed compliance costs and lost sales volume due to the price increase. The shocked supply function, $Supply_1$, is higher than the baseline supply function by the shock, $Shock=P_{L1}-P_L'$, where P_L' is the price corresponding to the new quantity on the baseline supply function, $Supply_0$. The proportion of compliance costs per unit that farms cannot pass on through the marketing chain is $P_{Lb}-P_L'$. Thus total costs to be absorbed at the farm level are $(P_{Lb}-P_L')Q_{L1}$. The lost sales volume is simply the change in quantity multiplied by the baseline price, $P_{Lb}(Q_{Lb}-Q_{L1})$. Summing these two quantities gives the farm level direct impact, $P_{Lb}Q_{Lb}-P_L'Q_{L1}$.

The EPA assumption of constant marginal costs precludes processors from absorbing passed through costs. For the more vertically integrated animal sectors, there is strong evidence that integrators do not absorb changes in input costs but quickly pass them on to the retail level (McIntosh et al., 1997). The direct impact on the processing sector is the change in quantity produced times its baseline price, $P_{Mb}(Q_{Mb}^S-Q_{M1}^S)$, shown in the Retail Product Market panel of Figure B-2.

There is also an impact on consumers who must devote more resources to buy a similar amount of animal products. This direct impact on consumers' spending is the change in price multiplied by the postregulation quantity, $(P_{M1}-P_{Mb})Q_{M1}^S$.

B.4.3 Input/Output Analysis

EPA applies Regional Input-Output Modeling System, version 2 (RIMS II)(USDC, 1997b) multipliers to estimate the effect of the proposed regulations on national employment (measured in terms of full-time equivalents) and economic output (measured in terms of changes in Gross Domestic Product). These estimated changes are based on the estimated direct impacts, described in the preceding section, which are in terms of dollars of industry output per year.

The published RIMS II multipliers apply to changes in industry final demand rather than changes in output. To apply to industry output, the row of published multipliers for the affected industry must be divided by the multiplier for that industry. The new row sum will be the output-driven multiplier for the industry (USDC, 1997b). All of the multipliers used in this analysis are output-driven. Table 4-14 presents the multipliers used in this analysis.

B.4.3.1 Employment

A RIMS II own-industry multiplier[5] expresses for each industry the number of full-time equivalent jobs per million dollars of industry output (USDC, 1997b). The employment multipliers are driven by a dollar measure, output, and so must be adjusted for inflation. The employment multipliers are derived from 1992 data. They are adjusted to the 1997 price levels of the baseline data using the Consumer Price Index for all urban consumers (Council of Economic Advisors, 2000). The direct impact on farm employment is:

$$\text{Direct Employment Impact} = (P_{L,b}Q_{L,b} - P_L^{/}Q_{L,1})\ E\ (\frac{CPI_{1992}}{CPI_{1997}}) \tag{16}$$

where prices and quantities are as previously defined and:

E = Own-industry RIMS II employment multiplier for production sector

CPI_{1992} = Consumer Price Index (CPI-U) for 1992

CPI_{1997} = Consumer Price Index (CPI-U) for 1997

Total effects multipliers, minus the own-industry portion, estimate the ripple effect of farm level changes on other industries throughout the national economy. Thus, the indirect employment effects are:

$$\text{Indirect Employment Impact} = (P_{L,b}Q_{L,b} - P_L^{/}Q_{L,1})\ (V - E)\ (\frac{CPI_{1992}}{CPI_{1997}}) \tag{17}$$

where V is the RIMS II total employment multiplier for the production sector, e.g. poultry and egg production. Processing industry and household indirect employment impacts are calculated similarly from the direct impacts on those industries. The agricultural component is subtracted from the processing industry multiplier to avoid counting the impact on farms twice.

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[5]See Section 4.4.1.2 for a discussion of input-output analysis, multipliers, and RIMS II. Households are treated as an industry.

B.4.3.2 National Output

EPA estimates the total reduction in national output (Gross Domestic Product) by multiplying the direct impacts by a RIMS II total output multiplier for the industry, adjusted to avoid double counting the agricultural component. The inflation adjustment used to calculate the indirect employment effects is unnecessary for output multipliers.

Farm, processing, and household impacts are added together to show total reductions. The netting out of own-industry and agricultural effects from the multipliers ensures that impacts are not double counted when sectors are added together.

Spending to build treatment lagoons and buy manure handling equipment is a stimulus to the national economy. Although many economists argue that spending for pollution control equipment should be considered a cost to “right past wrongs,” such spending does stimulate the economy and add jobs and income. None of the results presented in Section 5 include any stimulus effects. In most cases, a stimulus of this sort offsets the impacts of the regulatory action (see, for example, USEPA, 1998b, or USEPA, 2000c).

B.5 GLOSSARY OF NOTATION

Tables B-3, B-4, and B-5 indicate, respectively, the COSTBEN/EPA model variables, coefficients, and parameters used.

Table B-3. COSTBEN/EPA Model Variables

Symbol [a/]	Description	Units [b/]	Equations
Q_L^I	Quantity of farm product imported	head:BH; lbs:RTD; doz:L	1
P_L	Price of farm product	$/cwt:BHD; ¢/lb:RT; ¢/doz:L	1,2,3,4,6
P_L'	Price of farm product , postregulatory quantity on preregulatory supply function	$/cwt:BHD; ¢/lb:RT; ¢/doz:L	16, 17
Q_L^X	Quantity of farm product exported	head:BH; lbs:RTD; doz:L	2
Q_L	Quantity of farm product produced domestically	head:BH; lbs:RTD; doz:L	3, 5
Q_L^S	Quantity of farm product available for processing	head:BH; lbs:RTD; doz:L	4
Q_M^S	Quantity of net retail product demand	lbs:BDHRT; doz:L	5, 10
P_M	Price of retail product	$/lb:BH; index:D; ¢/lb:RT; ¢/doz:L	6,7,8,9,10,13
Q_M^I	Quantity of retail product imported	lbs:BDHRT; doz:L	7
Q_M^X	Quantity of retail product exported	lbs:BDHRT; doz:L	8
Q_M	Quantity of domestic retail product demand	lbs:BDHRT; doz:L	6, 9

Data variables and source for prices and quantities (production, utilization, and trade) used for this analysis are as follows (data are shown in Table 4-14):

Prices:

Beef: NCBA, 2000. Stat99_11.xls, Table 4.1, Farm-level=Choice fed steers, Cattle-fax average, carcass weight; Retail-level=Choice retail beef.

Dairy: USDA/ERS, 1998b. December 28, 1998, U.S. Dairy Situation at a glance. Farm-level=Milk eligible for fluid use; Retail-level=Consumer Price Index for all dairy products (1982-84=100).

Hog: Pork price spread tables at http://www.econ.ag.gov/Briefing/meatbrif/, see USDA/ERS, 1999c. January 26, 1999. Farm-level=51-52% lean, Hog, carcass price; Retail-level=Pork composite retail.

Poultry: All Prices from USDA/WAOB, 1999. p. 74 and 75.

Chicken: Farm-level=Broilers, Average price received by farmers, cents per liveweight pound; Retail-level=Young chicken, composite retail.

Turkey: Farm-level=Turkey, Average price received by farmers, cents per liveweight pound; Retail-level=Whole frozen birds.

Eggs: Farm-level=Table eggs, prices received by farmers (excludes hatching eggs); Retail-level=Grade A, Large

Table B-3. COSTBEN/EPA Model Variables (continued)
Quantities:

Beef: Farm-Level Domestic Production: USDA/ERS, 1998b. December 28, 1998, Meat Statistics, Commercial Slaughter, head (includes calves). Where necessary, head is converted to live weight based on 1997 annual average live weight of 1,173 lbs/head for cattle, USDA/NASS, 1998d, Livestock Slaughter, 1997 Annual Summary, Livestock Slaughter: Number of Head Slaughtered and Average Live Weight by Species and Month, United States, 1997;
Retail-Level Domestic Production: Beef & Veal: Putnam and Allshouse, 1999. Total Production.
Imports and exports: USDA/ERS, 1999d. November 23, 1999, Cumulative U.S. Livestock and Meat Imports and Exports, Cattle Imports and Exports, head; Beef &Veal Imports and Exports.

Dairy: Domestic Production: USDA/ERS, 1998b. December 28, 1998, U.S. Dairy Situation at a Glance, Milk Production, U.S. est.
Imports and exports: NMPF, 1999. Milk equivalent, total solids basis.

Hogs: Domestic Production: USDA/ERS, 1998b. December 28, 1998, Meat Statistics Commercial Slaughter, head; Imports and exports: USDA/ERS, 1999d. November 23, 1999, Cumulative U.S. Livestock and Meat Imports and Exports, head. Where necessary head is converted to live weight based on 1997 annual average live weight of 256 lbs/head, USDA/NASS, 1998d, Livestock Slaughter, 1997 Annual Summary, Livestock Slaughter: Number of Head Slaughtered and Average Live Weight by Species and Month, United States, 1997;
Pork Quantities: USDA/WAOB, 1999. p. 73. Total production, imports, and exports.

Poultry: All quantities from USDA/ERS, 1998a. May 21, 1998,
Poultry supply and utilization tables and Egg supply and utilization table.
Chicken: Carcass weight, Total of broilers and other chicken for Net RBC production, imports, and exports.
Turkey: Carcass weight, Net RBC production, imports, and exports.
Eggs: Egg Supply, million dozen, Total eggs, imports, and exports.

[a/] Q designates quantities and P designates prices. All farm product variables are subscripted L; retail market variables are subscripted M. This is a holdover from the red-meat-oriented COSTBEN model which dealt solely in livestock and meat. When necessary, an additional subscript is added to any variable to denote preregulatory and postregulatory values. Subscript b indicates baseline, preregulatory value; subscript 1 denotes shocked, postregulatory value. Superscript I indicates imports, X indicates exports, and S indicates a net total of domestic products, imports, and exports.

[b/] B=Beef, D=Dairy, H=Hogs, R=Broilers, L=Layers, T=Turkeys. Cattle and Hog number of head is converted to pounds at the rate of 1,173 lb/head for cattle and 256 lb/head for hogs (USDA/NASS, 1998d).

Table B-4. COSTBEN/EPA Model Coefficients

Symbol	Description	Units [a/]	Equations
α_1	Intercept of farm product import supply	head:BH; lbs:RTD; doz:L	1
β_1	Coefficient on P_L of farm product import supply	head/$/cwt:BH; lbs/$/lb:D; lbs/¢/lb:RT; doz/¢/doz:L	1
α_2	Intercept of farm product export demand	head:BH; lbs:RTD; doz:L	2
β_2	Coefficient on P_L of farm product export demand	head/$/cwt:BH; lbs/$/lb:D; lbs/¢/lb:RT; doz/¢/doz:L	2
α_3	Intercept of domestic farm product supply	head:BH; lbs:RTD; doz:L	3
β_3	Coefficient on P_L of domestic farm product supply	head/$/cwt:BH; lbs/$/lb:D; lbs/¢/lb:RT; doz/¢/doz:L	3
α_0	Intercept of trade-adjusted farm product supply, $= \alpha_1 - \alpha_2 + \alpha_3$	head:BH; lbs:RTD; doz:L	4,13
β_0	Coefficient on P_L of trade-adjusted farm product supply, $= \beta_1 - \beta_2 + \beta_3$	head/$/cwt:BH; lbs/$/lb:D; lbs/¢/lb:RT; doz/¢/doz:L	4,13
δ_1	Coefficient on Q_M^S of marginal cost of processing services equation (assumed to be zero)	$/lb/lb:BH; index/lb:D; ¢/lb/lb:RT; ¢/doz/doz:L	6a
ϕ_1	Intercept of marginal cost of processing services equation	$/lb:BH; index:D; ¢/lb:RT; ¢/doz:L	6a,6,13
σ_1	Intercept of retail product import supply	lbs:BDHRT; doz:L	7
γ_1	Coefficient on P_M of retail product import supply	lbs/$/lb:BD; lbs/¢/lb:HRT; doz/¢/doz:L	7
σ_2	Intercept of retail product export demand	lbs:BDHRT; doz:L	8
γ_2	Coefficient on P_M of retail product export demand	lbs/$/lb:BD; lbs/¢/lb:HRT; doz/¢/doz:L	8
σ_3	Intercept of domestic retail product demand	lbs:BDHRT; doz:L	9
γ_3	Coefficient on P_M of domestic retail product demand	lbs/$/lb:BD; lbs/¢/lb:HRT; doz/¢/doz:L	9
σ_0	Intercept of trade-adjusted retail product demand, $= \sigma_3 + \sigma_2 - \sigma_1$	lbs:BDHRT; doz:L	10,13
γ_0	Coefficient on P_M of trade-adjusted retail product demand, $= \gamma_3 + \gamma_2 - \gamma_1$	lbs/$/lb:BD; lbs/¢/lb:HRT; doz/¢/doz:L	10,13
$\alpha_3^{Shocked}$	Shocked Intercept of domestic farm product supply	lbs:BDHRT; doz:L	15

[a/]B=Beef, D=Dairy, H=Hog, R=Broiler, L=Layer, T=Turkey. Beef and Hog number of head is converted to pounds at the rate of 1,173 lb/head for beef and 256 lb/head for hogs (USDA/NASS, 1998d).

Table B-5. COSTBEN/EPA Model Parameters

Symbol	Description	Units [a/]	Related Coefficient
Conv	Conversion Ratio from farm to retail	lbs/head:BH; lb retail/lb farm:DRT doz retail/doz farm:L	none
LRSE	Long-run farm product supply elasticity	unitless	β_3
LMDE	Long-run retail product demand elasticity	unitless	γ_3
LMSE	Import supply elasticity of farm product	unitless	β_1
LXDE	Export demand elasticity of farm product	unitless	β_2
MMSE	Import supply elasticity of retail product	unitless	γ_1
MXDE	Export demand elasticity of retail product	unitless	γ_2
Shock	Annualized compliance costs per unit of farm product	\$/cwt:BHD; ¢/lb:RT; ¢/doz:L	$\alpha_3^{Shocked}$
E	Own-industry employment multiplier	jobs/\$ output	none
V	Industry total employment multiplier	jobs/\$ output	none
CPI_{1992}	Consumer Price Index for all urban consumers (1982-84=100) for 1992, = 140.3	unitless	none
CPI_{1997}	Consumer Price Index for all urban consumers (1982-84=100) for 1997, = 160.5	unitless	none

[a/] B=Beef, D=Dairy, H=Hog, R=Broiler, L=Layer, T=Turkey.

APPENDIX C

SUMMARY OF DEMAND AND SUPPLY ELASTICITY LITERATURE

This appendix presents the results of EPA's literature review and the magnitudes of published demand and supply elasticities for the beef, dairy, pork, and poultry sectors.

EPA has reviewed the available literature on the demand and supply characteristics of the beef, dairy, pork, and poultry markets (ERG, 1999a and ERG, 1999b). These expanded reviews include an annotated summary of each study and are contained in the record (DCN 70642 and DCN 70362). The majority of the models in the literature are based on econometric estimations of various demand and supply system specifications, such as the Almost Ideal Demand System (AIDS) and the Rotterdam model. However, given the prevalence of non-theoretical approaches to estimating demand and supply responses in the literature using such techniques as vector autoregression (VAR), EPA also includes those studies in the tables where applicable.

EPA summarizes the estimates of demand and supply elasticities across a wide range of poultry meat products including beef, milk, broilers, chicken[1], turkey, and poultry meat as a composite commodity. EPA groups the market studies in a general poultry meat category because many market studies include either both turkey and chicken elasticities or a general poultry category.

[1]Some market studies identified demand elasticities for "chickens" instead of "broilers." EPA has identified these elasticity estimates as chicken to be consistent with the author's language.

Table C-1. Demand Elasticities for Beef Products Ranked from the Lowest Estimate to the Highest Estimate

Source	**Elasticity Estimate**
Eales and Unnevehr (1988)	-2.59 (hamburger)
Capps (1989)	-1.27 (roast beef)
Brester and Wohlgenant (1991)	-1.155 (fed beef)
Heien and Pompelli (1988) [a/]	-1.11 (roast)
Moschini and Meilke (1989)	-1.05 (beef)
Huang and Hahn (1995) [a/]	-1.036 (high quality beef)
Gao and Shonkwiler (1993) [a/]	-1.03 (beef)
Kesavan et al. (1993) [a/]	-1.02 (long-run, beef)
Brester and Wohlgenant (1991)	-1.015 (ground beef)
Ospina and Shumway (1979)	-0.98 (fed beef; Langemeier and Thompson, 1967)
Alston and Chalfant (1993)	-0.98 (beef)
Choi and Sosin (1990)	-0.971 (red meat)
Brester (1996)	-0.96 (ground beef)
Chavas (1983)	-0.916 (beef)
Hahn (1994) [a/]	-0.869 (beef)
Eales and Unnevehr (1993)	-0.850 (beef)
Heien and Pompelli (1988) [a/]	-0.85 (ground beef)
Moschini, Moro, and Green (1994)	-0.84 (beef)
Ospina and Shumway (1979)	-0.83 (fed beef; Freebairn and Rausser, 1975)
Brester and Wohlgenant (1991)	-0.811 (table-cut beef)
Brester (1996)	-0.80 (table-cut beef)
Wohlgenant (1989)	-0.76 (beef and veal)
Marsh (1992)	-0.742 (retail beef)
Heien and Pompelli (1988) [a/]	-0.73 (steaks)
Capps (1989)	-0.72 (steak)
Brester (1996)	-0.70 (beef)
Eales and Unnevehr (1988)	-0.68 (table-cut beef)

Table C-1. Demand Elasticities for Beef Products Ranked from the Lowest Estimate to the Highest Estimate (continued from previous page)

Source	Elasticity Estimate
Marsh (1991)	-0.66 (choice slaughter beef)
Huang (1993)	-0.6212 (beef and veal)
Huang (1986)	-0.6166 (beef and veal)
Hahn (1988)	-0.58 (beef)
Eales and Unnevehr (1988)	-0.570 (beef)
Ospina and Shumway (1979)	-0.57 (wholesale beef)
Marsh (1992)	-0.536 (farm beef)
Marsh (1992)	-0.495 (wholesale beef)
Arzac and Wilkinson (1979)	-0.49 (fed beef)
Brester and Wohlgenant (1993) [a/]	-0.45 (beef)
Huang and Hahn (1995) [a/]	-0.401 (manufacturing grade beef)
Capps (1989)	-0.15 (ground beef)

[a/] As cited in Hahn (1996a).

Table C-2. Supply Elasticities for Beef Products Ranked from the Lowest Estimate to the Highest Estimate

Source	Elasticity Estimate
Marsh (1994)	-0.17 (short-run, fed cattle)
Ospina and Shumway (1979)	0.06 (steer-heifer fed beef; Folwell and Shapouri, 1977)
Ospina and Shumway (1979)	0.14 (slaughter beef)
Marsh (1994)	0.14 (all beef; Freebairn and Rausser, 1975)
Marsh (1994)	0.14 (fed beef; Shuib and Menkhaus, 1977)
Marsh (1994)	0.200 (wholesale fed beef; Bedinger and Bobst, 1988)
Marsh (1994)	0.23 (fed beef; Langemeier and Thompson, 1967)
Marsh (1994)	0.606 (intermediate run, fed cattle)
Marsh (1994)	0.993 (beef; Tvedt, et al., 1991)
Marsh (1994)	3.24 (long-run, fed cattle)
Buhr (1993)	9.505 (beef, long-run - 5 years) [a/]

[a/] The estimate does not reflect CPT because it is not comparable to the other elasticity estimates. The reported figure is the impact of a 10 percent change in farm price rather than the standard 1 percent. Given the nonlinear nature of the system, the figure cannot be translated into a standard elasticity estimate via division by 10.

Table C-3. Demand Elasticities for Milk Ranked from the Lowest Estimate to the Highest Estimate

Source	Elasticity Estimate
Holt and Aradhyula (1995)	-0.65 (long-run, fluid milk)
Tanjuakio, Gempesaw, and Elterich (1992)	-0.48 (fluid milk; Bailey, et al., 1990)
Tanjuakio, Gempesaw, and Elterich (1992)	-0.47 (manufactured milk)
Tanjuakio, Gempesaw, and Elterich (1992)	-0.43 (manufactured milk; Kaiser and Tauer, 1988)
Tanjuakio, Gempesaw, and Elterich (1992)	-0.37 (manufactured milk; Bailey et al, 1990)
Huang (1986)	-0.2580 (fluid milk)
Huang (1993)	-0.2472
Holt and Aradhyula (1995)	-0.23 (short-run, fluid milk)
Tanjuakio, Gempesaw, and Elterich (1992)	-0.19 (fluid milk)
Tanjuakio, Gempesaw, and Elterich (1992)	-0.05 (fluid milk; Kaiser and Tauer, 1988)

Table C-4. Supply Elasticities for Milk Ranked from the Lowest Estimate to the Highest Estimate

Source	Elasticity Estimates
Short-Run	
Howard and Shumway (1988)	-0.075 (milk, short-run)
Chavas and Klemme (1986)	0.07 to 0.16 (milk, short-run; Hammond et al., 1974, Chen et al., 1972, and Hutton and Helmberger, 1982)
Tanjuakio, Gempesaw, and Elterich (1992)	0.11 to 0.43 (short-run, milk; Weersink and Tauer, 1990)
Weersink and Howard (1990)	0.118 to 0.639 (short-run, milk)
Long-Run	
Huy et al. (1988)	-0.322 to .884 (milk)
Blayney and Mittelhammer (1990)	0.12 (milk, at 1 year; Dahlgran, 1985)
Chavas and Klemme (1986)	0.12 (milk, at 1 year)
Chavas, Kraus, and Jesse (1990)	0.139 (milk, at 1 year)
Chavas and Klemme (1986)	0.14 (milk, long-run; Hammond, 1974)
Howard and Shumway (1988)	0.144 (milk, long-run)

Table C-4. Supply Elasticities for Milk Ranked from the Lowest Estimate to the Highest Estimate (continued from previous page)

Source	Elasticity Estimates
Buxton (1985)	0.175 (milk, at 1 year)
Tanjuakio, Gempesaw, and Elterich (1992)	0.016 to 0.29 (milk)
Tanjuakio, Gempesaw, and Elterich (1992)	0.25 to 0.46 (long-run, milk; Weersink and Tauer, 1990),
Buxton (1985)	0.510 (milk, at 4 years)
Weersink and Howard (1990)	0.145 to 0.664 (long-run, milk)
Blayney and Mittelhammer (1990)	0.8932 (milk)
Chavas, Kraus, and Jesse (1990)	1.527 (milk, at 10 years)
Chavas and Klemme (1986)	2.20 (milk, long-run; Dahlgran, 1985)
Chavas and Klemme (1986)	2.46 (milk, at 10 years)
Chavas and Klemme (1986)	2.53 (milk, long-run; Chen et al., 1972)
Chavas, Kraus, and Jesse (1990)	4.787 (milk, at 29 years)
Chavas and Klemme (1986)	6.69 (milk, at 30 years)

Table C-5. Demand Elasticities for Pork Ranked from the Lowest Estimate to the Highest Estimate

Source	Elasticity Estimate
Eales and Unnevehr (1993)	-1.234 (pork - AIDS with SI)
Kesavan et al (1993) [a/]	-0.99 (pork - long-run)
Gao and Shonkwiler (1993) [a/]	-0.95 (pork)
Arzac and Wilkinson (1979)	-0.87 (pork)
Moschini and Meilke (1989)	-0.839 (pork)
Huang and Hahn (1995) [a/]	-0.838 (pork)
Huang (1994)	-0.8379 (pork)
Capps (1989)	-0.8279 (pork loin)
Eales and Unnevehr (1993)	-0.801 (pork - AIDS without SI)
Lemieux and Wohlgenant (1989)	-0.80 (pork)
Hahn (1988)	-0.784 (pork)
Brester and Wohlgenant (1991)	-0.779 (pork - ground beef model)
Brester and Wohlgenant (1991)	-0.775 (pork - nonfed model)

Table C-5. Demand Elasticities for Pork Ranked from the Lowest Estimate to the Highest Estimate (continued from previous page)

Source	Elasticity Estimate
Eales and Unnevehr (1988)	-0.762 (pork - aggregate system)
Huang (1986)	-0.7297 (pork)
Huang (1993)	-0.7281 (pork)
Chavas (1983)	-0.723 (pork - SC)
Chavas (1983)	-0.714 (pork - WSC)
Capps (1989)	-0.7005 (pork chops)
Moschini, Moro, and Green (1994)	-0.68 to -0.72 (pork)
Hahn (1994) [a/]	-0.699 (pork)
Brester and Schroeder (1995)	-0.69 (pork)
Eales and Unnevehr (1988)	-0.565 (pork - disaggregated system)
Eales et al (1998)	-0.52 (pork)
Wohlgenant (1989)	-0.51 (pork - unrestricted)
Capps and Schmitz (1991)	-0.4510 (pork)
Wohlgenant (1989)	-0.36 (pork - restricted)
Capps (1989)	-0.3596 (ham)
Capps (1989)	-0.2639 (composite pork commodity)
Alston and Chalfant (1993)	-0.17 (pork - Rotterdam)
Alston and Chalfant (1993)	-0.07 (pork - AIDS)

[a/] As cited in Hahn (1996a).

Table C-6. Supply Elasticities for Pork Ranked from the Lowest Estimate to the Highest Estimate

Source	**Elasticity Estimate**
Short-Run	
Holt and Johnson (1988)	0.007 (pork, short-run - 3 quarters)
Heien (1975)	0.09 (pork) [a/]
Meilke et al. (1974)	0.16 (hog, short-run - GDL)
Meilke et al. (1974)	0.17 (hog, short-run - PDL)
Lemieux and Wohlgenant (1989)	0.4 (pork, short-run)
Buhr (1993)	2.63 (pork, short-run - 1 quarter) [b/]
Intermediate-Run	
Meilke et al. (1974)	0.24 (hog, intermediate-run - PDL)
Holt and Johnson (1988)	0.338 (pork, intermediate-run - 10 quarters)
Lemieux and Wohlgenant (1989)	1.8 (pork, intermediate-run
Long-Run	
Meilke et al. (1974)	0.43 (hog, long-run - GDL)
Meilke et al. (1974)	0.48 (hog, long-run - PDL)
Holt and Johnson (1988)	0.628 (pork, long-run - 40 quarters)
Buhr (1993)	7.35 (pork, long-run - 5 years) [b/]

[a/] The reported figure is the elasticity of total number of pigs slaughtered with respect to the ratio of farm to retail price of pork.
[b/] The estimate does not reflect CPT because it is not comparable to the other elasticity estimates. The reported figure is the impact of a 10 percent change in farm price rather than the standard 1 percent. Given the nonlinear nature of the system, the figure cannot be translated into a standard elasticity estimate via division by 10.

Table C-7. Demand Elasticities for Broilers/Chickens Ranked from the Lowest to the Highest Estimate

Source	**Elasticity Estimate**
Kesavan et al (1993) [a/]	-1.25 (chicken - long-run)
Arzac and Wilkinson (1979)	-0.98 (chicken)
Alston and Chalfant (1993)	-0.94 (chicken - AIDS and Rotterdam)
Eales and Unnevehr (1988)	-0.677 (chicken - whole bird)
Capps (1989)	-0.6557 (chicken)
Eales and Unnevehr (1988)	-0.610 (chicken - parts/processed)
Huang (1986)	-0.5308 (chicken)
Gao and Shonkwiler (1993) [a/]	-0.47 (chicken)
Huang (1993)	-0.3723 (chicken)
Hahn (1994) [a/]	-0.299 (chicken)
Eales and Unnevehr (1988)	-0.276 (chicken)
Eales and Unnevehr (1993)	-0.233 (chicken - AIDS with SI)
Huang and Hahn (1995) [a/]	-0.197 (broiler)
Huang (1994)	-0.1969 (broiler)
Eales and Unnevehr (1993)	-0.162 (chicken - AIDS without SI)
Eales et al (1998)	-0.15 (chicken - Model 3)
Eales et al (1998)	-0.14 (chicken - Model 1)
Hahn (1988)	-0.140 (chicken)
Eales et al (1998)	-0.13 (chicken - Model 2)
Moschini and Meilke (1989)	-0.104 (chicken)

[a/] As cited in Hahn (1996a).

Table C-8. Supply Elasticities for Broilers/Chickens Ranked from the Lowest to the Highest Estimate

Source	Elasticity Estimate
Short-Run	
Chavas and Johnson (1982)	0.064 (broiler, short-run)
Chavas (1982)	0.072 (broiler, short-run) [c/]
Holt and Aradhyula (1990)	0.216 (broiler, short-run-adaptive expectations) [a/]
Holt and Aradhyula (1990)	0.232 (broiler, short-run - GARCH) [a/]
Aradhyula and Holt (1989)	0.305 (broiler, short-run) [a/]
Holt and Aradhyula (1990)	0.399 (broiler, long-run - adaptive expectations) [a/]
Buhr (1993)	0.49 (chicken, short-run - 1 quarter) [b/]
Long-Run	
Holt and Aradhyula (1990)	0.399 (broiler, long-run - adaptive expectations) [a/]
Holt and Aradhyula (1990)	0.587 (broiler, long-run - GARCH) [a/]
Buhr (1993)	0.68 (chicken, long-run - 5 years) [b/]

[a/] The reported elasticity figure is based on the *expected* rather than the actual mean price of broilers.
[b/] The estimate does not reflect CPT because it is not comparable to the other elasticity estimates. The reported figure is the impact of a 10 percent change in farm price rather than the standard 1 percent. Given the nonlinear nature of the system, the figure cannot be translated into a standard elasticity estimate via division by 10.
[c/] The reported figure is the elasticity of supply with respect to the one-quarter lagged product price.

Table C-9. Demand Elasticities for Eggs Ranked from the Lowest Estimate to the Highest Estimate

Source	**Elasticity Estimate**
Putler (1992)	-0.78 (for price increase)
Gerra (1959) [a/]	-0.40
Chavas and Johnson (1981)	-0.34 (short-run)
Putler (1992)	-0.33 (for price decrease)
Chavas and Johnson (1981)	-0.3298 (long-run)
George and King (1971) [a/]	-0.318
Brown and Schrader (1990)	-0.17 (with TIME, WW, CHOL)
Brown and Schrader (1990)	-0.164 (with TIME, CHOL)
Wohlgenant (1989)	-0.15 (unrestricted)
Huang (1986)	-0.1452
Huang and Haidacher (1983)	-0.14
Brown and Schrader (1990)	-0.129 (with TIME, WW)
Huang (1993)	-0.1103
Brown and Schrader (1990)	-0.109 (with WW, CHOL)
Brown and Schrader (1990)	-0.094 (with TIME)
Brown and Schrader (1990)	-0.089 (with CHOL)
Wohlgenant (1989)	-0.05 (restricted)
Brown and Schrader (1990)	-0.043 (with WW)
Brown and Schrader (1990)	-0.022 (no structural change)

[a/] As cited in Chavas and Johnson (1981).

Table C-10. Supply Elasticities for Eggs Ranked from the Lowest Estimate to the Highest Estimate

Source	Elasticity Estimate
Short-Run	
Chavas and Johnson (1981)	0.031
Long-Run	
Chavas and Johnson (1981)	0.9415 (long-run)

Table C-11. Demand Elasticities for Turkey Ranked from the Lowest Estimate to the Highest Estimate

Source	Elasticity Estimate
Huang (1986)	-0.6797 (turkey)
Eales et al (1998)	-0.63 (turkey - Model 1)
Huang (1993)	-0.5345 (turkey)
Hahn (1994) [a/]	-0.459 (turkey)
Soliman (1971)	-0.412 (turkey - 3SLS)
Soliman (1971)	-0.411 (turkey - LISE)
Soliman (1971)	-0.394 (turkey - 2SLS)
Soliman (1971)	-0.372 (turkey - OLS)

[a/] As cited in Hahn (1996a).

Table C-12. Supply Elasticities for Turkey Ranked from the Lowest Estimate to the Highest Estimate

Source	Elasticity Estimate
Short-Run	
Chavas and Johnson (1982)	0.210 (turkey, short-run)
Chavas (1982)	0.222 (turkey, short-run) [a/]
Soliman (1971)	0.353 (turkey, short-run) [b/]
Long-Run	
Soliman (1971)	0.518 (turkey, long-run) [b/]

[a] The reported figure is the elasticity of supply with respect to the one-quarter lagged product price.
[b] The reported figure is the elasticity of turkey production with respect to the lagged turkey-feed price ratio.

APPENDIX D

SENSITIVITY ANALYSES

This appendix presents EPA's analyses to test the sensitivity of the CAFO model and the national market model to the model input assumptions. For the CAFO models, EPA conducts a sensitivity analysis of the financial operating conditions assumed in the baseline by varying key variables used in the analysis and also by using differing the methodological approach used to assess impacts (Section D.1). EPA also tests the results of the national market model for livestock and poultry products to varying commodity prices and price response assumptions (Section D.2). The results of these sensitivity analyses show that EPA's CAFO model and market model are reasonably stable over a realistic range of potential variability in impact and market measures.

For the purpose of this discussion, the "Main Analysis Value" corresponds to data used by EPA based on the 1997 ARMS data that are assumed to depict baseline financial conditions at model CAFOs for EPA's main analysis (results presented in Section 5.2). The "Sensitivity Analysis Value" corresponds to data that have been modified by EPA to examine variability of the key input assumptions used for the sensitivity analysis presented here. In each case where the baseline data have been varied (or the approach varied), all other key input variables and assumptions are assumed to be the same as they are in the main analysis.

During the development of EPA's analytical model to examine the regulatory costs and impacts that might accrue to CAFOs as a result of the proposed regulations, EPA also conducted extensive sensitivity analyses with respect to the estimated compliance costs for model CAFOs developed by EPA. These results are presented in the *Development Document* that supports this rulemaking (USEPA, 2000a). This appendix describes the results of EPA's sensitivity analysis to EPA's financial models only.

D.1 CAFO MODEL SENSITIVITY ANALYSIS

To examine the stability of the results of EPA's CAFO level analysis, EPA conducts various sensitivity analyses that examine the results of EPA's analysis under both differing baseline value assumptions, as well as differing methodological approaches. EPA examines the results of its analysis under differing baseline value assumptions for three key variables, including: modified gross farm revenue values to reflect lower farm revenues from an operation's livestock business for use in a sales test (Section D.1.1), modified net cash income to reflect higher operating expenses for use in a discounted cash flow analysis (Section D.1.4), and modified debt-to-asset ratios to reflect greater financial risk for use in a financial ratio analysis (Section D.1.5). EPA also investigates two alternative methods for undertaking the sales test. These include: use of pre-tax versus post-tax gross farm revenues for use in a sales test (Section D.1.3) and use of livestock income variables only versus entity farm revenue also for use in a sales test (Section D.1.2).

EPA conducts these sensitivity analyses by estimating the number of adversely affected operations using the approach for the main analysis (described in Section 4.2.5). Accordingly, EPA investigates three key financial criteria used in the impact analysis (sales tests, discounted cash flow, and debt-to-asset ratios) and classifies CAFO level economic impacts into three categories—affordable, moderate, and stress. Facilities that fall within the "stress" impact category are considered by EPA to be vulnerable to closure and may indicate that an option is not economically achievable, subject to other considerations. As in the main analysis, for some sectors EPA evaluates impacts under both a Zero and a Partial cost passthrough scenario (CPT), using the approach described in Section 4.2.6 of this report.

EPA re-examines the results of its economic analysis by comparing these results to the results of these sensitivity analyses. Differences are measured in terms of the number of affected operations under the stress impact category. The ELG Option and NPDES Scenario combination examined for this analysis are the proposed BAT Option and Scenario 4b. This scenario would apply to all CAFOs with more than 300 AU. Although EPA is not proposing this scenario for the CAFO regulations, EPA evaluates results under this scenario for these sensitivity analyses since this scenario results in the greatest number of facilities affected and thus allows EPA to more fully evaluate the results of its financial models used in the main analysis.

EPA decided to conduct some of these sensitivity analyses because of perceived limitations with the ARMS financial data that are used for EPA's CAFO analysis. Among the limitations of these data are that they reflect average financial conditions across an entire sector and may not reflect conditions at different subsectors. Variance analysis of these data also are not available for use in defining a distribution of financial characteristics within a model CAFO. The ARMS data are also limited in that they represent conditions at a single point in a single year (1997), and therefore do not embody the expected variability of farm financial conditions year-to-year.[1] These and other limitations of the ARMS data for use in this analysis are discussed in Section 4 and in other sections throughout this report, including Sections 6, 7, and 8.

The concern is that use of these limitations may result in understating EPA's economic impact analysis by overstating a model CAFO's baseline financial conditions and its ability to pay for on-farm improvements under the proposed regulation (i.e., concluding that a model CAFO is able to afford the estimated regulatory costs when, in fact, it cannot). The possibility that EPA may be understating financial conditions at a model CAFO is less problematic since this would mean that EPA's analysis is overly conservative (i.e., overstates impacts by not fully accounting for an average facility's ability to afford the estimated regulatory costs when, in fact, it can could afford costs that are even higher).

[1]Attachment 1 at the end of this appendix shows selected annual market data for each sector from 1992 to 2000, where available. For most sectors, the data reviewed for 1997 are within the range of the period average.

EPA recognizes the limitations of the ARMS financial data for use in this analysis; however, EPA also believes that use of these data may produce overly conservative impact results. The ARMS data are representative of the population, which contains more smaller-sized operations and fewer larger-sized operations, such as those that would be subject to the proposed regulations. The ARMS data also include all types of operations—noncommercial, higher cost producers, as well as smaller scale production units—which may also result in the average financial statistics being lower than might be expected for the regulated population. Financial conditions at the larger-sized facilities that would be defined as CAFOs are likely more favorable than at smaller operations that are more representative of the ARMS data. Since the ARMS data are likely less representative of the types of larger scale operations that would be affected by the proposed CAFO regulations, use of these data may overstate estimated impacts to model facilities. In addition, on the cost side, EPA believes that its estimated costs are conservative, as documented in the *Development Document* (USEPA, 2000a).

D.1.1 Sales Test Analysis (Lower Livestock Revenue)

The sensitivity analysis described in this appendix section assesses EPA assumptions of the baseline conditions as they affect the results of EPA's sales test. EPA's main analysis evaluates impacts using gross farm revenue from the 1997 ARMS data provided by USDA and derived by EPA on a per-animal basis using available data from ARMS that correspond to the financial data (described in Section 4). These data are average and may not reflect conditions at some operations that may receive lower than average national revenues (e.g., due to differences in prices received by producers).

To evaluate the baseline assumptions on revenues and to account for revenue differences among producers, EPA modifies the baseline data used in the main analysis by subtracting 10 percent off the livestock portion of total gross farm revenue and recalculating total revenues, assuming that the non-livestock revenue portion of revenue remains constant. Table D-1 presents a comparison of the revenues used in the main analysis and the modified revenues used in this sensitivity analysis (expressed on a per-animal basis).

Table D-2 compares the results of EPA's sensitivity analysis to the results of the main analysis. Under a zero CPT assumption, the percentage of CAFOs experiencing financial stress increases from 5.6 percent in the main analysis to 6.0 percent of all CAFOs in the sensitivity analysis. More CAFOs are estimated to experience financial stress in the fed cattle, heifer, and broiler sectors in the sensitivity analysis. Under a partial CPT assumption, an additional 200 CAFOs (990 CAFOs versus 790 CAFOs) are estimated to experience financial stress under the alternative revenue assumption compared to the main analysis. As in the main analysis, no hog or broiler operations are expected to experience financial stress under a partial CPT assumption. The percentage of operations experiencing financial stress assuming partial CPT increases from 1.7 percent (main analysis) to 2.2 percent (sensitivity analysis) of all CAFOs. Based on the results of this sensitivity analysis, EPA would likely not change the proposal made in the main analysis that the proposed CAFO regulations would be economically achievable.

Table D-1. Baseline Revenues in Main Analysis and Sensitivity Analysis (Lower Livestock Revenues)

Sector	Region	Facility Size Grouping	Main Analysis Revenue/Head	Sensitivity Analysis Revenue/Head
Beef	MW	Large	$861.83	$810.58
		Medium	$534.68	$502.00
	CE	Large	$854.00	$806.09
		Medium	$501.99	$468.00
Dairy	MW	Large	$2,612.95	$2,365.97
		Medium	$2,498.11	$2,273.14
		Small	$2,619.74	$2,404.92
	PA	Large	$2,567.29	$2,326.12
		Medium	$2,342.77	$2,126.16
Hog	MA	Large	$83.60	$78.90
		Medium	$296.66	$278.00
	MW	Large	$228.99	$210.38
		Medium	$303.89	$284.59
		Small	$606.13	$575.40
Broiler	MA	Large	$1.13	$1.11
		Medium	$1.47	$1.45
	SO	Large	$1.16	$1.14
		Medium	$1.42	$1.41
Layer	MW/MA	All	$24.63	$22.93
Turkey	MW/MA	All	$20.06	$18.42
		Medium	$11.24	$10.60

Source: Data used for main analysis are USDA/ERS (1999a), derived on a per-animal basis by EPA. Data used for sensitivity analysis are derived from the data in the main analysis, with USEPA assumptions (adjusts the USDA-reported livestock portion of total farm revenue is 10 percent lower; farm revenue from other sources remain constant). Table 4-1 defines regions and facility size groups.

Table D-2. Number of CAFOs Affected Assuming Alternative Assumption (Lower Livestock Revenues)

Sector	No. of CAFOs	Scenario 4b–Sensitivity Analysis			Scenario 4b–Main Analysis		
		Aff.	Mod.	Stress	Aff.	Mod.	Stress
		(number)			(number)		
Fed Cattle	4,070	2,780	1,070	230	2,880	1,150	40
Veal	210	210	0	0	210	0	0
Heifer	1,050	690	300	60	850	150	50
Dairy	7,140	5,590	850	700	6,010	440	700
Hogs (Zero CPT)	14,370	12,660	290	1,420	12,710	240	1,420
Hogs (Partial CPT)	14,370	14,250	120	0	14,370	0	0
Broilers (Zero CPT)	14,140	0	13,500	640	1,960	11,860	320
Broilers (Partial CPT)	14,140	9,940	4,200	0	12,690	1,450	0
Layers - Wet	360	360	0	0	360	0	0
Layers - Dry	1,700	1,700	0	0	1,700	0	0
Turkeys	2,100	1,990	110	0	1,990	110	0
Total (Zero CPT)	45,140	25,980	16,120	3,050	28,680	13,950	2,520
Total (Partial CPT)	**45,140**	**37,500**	**6,650**	**990**	**41,070**	**3,300**	**790**

Source: USEPA. Numbers may not add due to rounding.
Evaluated for the BAT Option and Scenario 4b (Options/Scenarios are defined in Table 3-1). Category definitions (“Affordable,” “Moderate” and “Stress”) are provided in Table 4-13.

D.1.2 Sales Test Analysis (Livestock Revenue Only)

The sensitivity analysis described in this appendix section assesses a change in methodology, not a change in baseline assumptions. As described in Section 4, EPA's main analysis evaluates cost-to-sales ratios (among other criteria) using financial data for the farm operation as a whole and does not differentiate between an operation's livestock and other business enterprises (discussed in Section 4). EPA conducts this sensitivity analysis to examine whether the results of the analysis would differ substantially if only the livestock portion of a model facility's farm revenue were used to evaluate cost-to-sales ratios in the analysis (i.e., to examine product line closures). These revenue data are from the 1997 ARMS data. However, the ARMS data do not differentiate between an operation's cost of production by enterprise; as a result, the cash flow portion of this analysis uses net cash flow based on an operating costs at the entity level.

Table D-3 presents a comparison of the revenues used in the main analysis and the modified revenues used in this sensitivity analysis (expressed on a per-animal basis). As shown, the reported ARMS data show that livestock revenues comprise roughly one-half of an entity's operating revenue for most sectors. In the broiler sector, however, livestock revenues are up to ten times lower than those reported for the entire operation (Table D-3).[2] As discussed in Section 4 of this report, EPA believes that an analysis that looks only at an operation's livestock revenue and not that of an entity may be unrealistic and overly conservative.

Table D-4 compares the results of EPA's sensitivity analysis to the results of the main analysis. Under a zero CPT assumption, an additional number of CAFOs are estimated to experience financial stress in the fed cattle, heifer, hog, and turkey sectors. All broiler operations are estimated to experience financial stress even under assumptions of partial cost passthrough. As in the main analysis, no hog operations are expected to experience financial stress under a partial CPT assumption. Under a partial CPT assumption—excluding estimated impacts to broiler operations—an additional 660 CAFOs (1,450 CAFOs versus 790 CAFOs) are estimated to experience financial stress under the alternative revenue assumption compared to the main analysis. Disregarding the broiler sector impacts, the percentage of CAFOs considered to experience financial stress increases from 2.5 percent (main analysis) to 4.7 percent (sensitivity analysis) of all CAFOs under a partial cost passthrough assumption.

Despite assumptions of cost passthrough, the results for broilers continue to show a high number of CAFOs in the stress category. EPA considers these impacts to be overstated because the overall approach overstates costs (i.e., costs are entity level and not by enterprise) and does not reflect production cost savings to contract growers in some sectors (see Section 2). Given considerations about the appropriateness of this approach and the use of these data for this analysis, EPA would likely not change its general approach that assesses impacts using entity level

[2]The derived revenue per broiler estimate approximates the per-unit revenues received by a contract grower in the broiler sector, as reported by Perry (1999).

financial data. Aside from the estimated impacts to the broiler sector, EPA would likely not change its proposal of economic achievability if livestock revenues had been used to judge impacts. For the broiler sector, EPA would likely argue that this approach does not appropriately measure impacts and thus cannot be used to assess economic achievability.

Table D-3.   Baseline Revenues in Main Analysis and Sensitivity Analysis (Livestock Revenues Only)

Sector	Region	Facility Size Grouping	Main Analysis Entity Revenue per Head	Sensitivity Analysis Entity Revenue per Head
Beef	MW	Large	$861.83	$512.46
		Medium	$534.68	$328.65
	CE	Large	$854.00	$479.09
		Medium	$501.99	$339.85
Dairy	MW	Large	$2,612.95	$2,649.82
		Medium	$2,498.11	$2,249.62
		Small	$2,619.74	$2,148.21
	PA	Large	$2,567.29	$2,411.70
		Medium	$2,342.77	$2,166.11
Hog	MA	Large	$83.60	$46.94
		Medium	$174.47	$101.69
	MW	Large	$228.99	$186.19
		Medium	$303.89	$192.93
		Small	$606.13	$307.26
Broiler	MA	Large	$1.13	$0.16
		Medium	$1.47	$0.18
	SO	Large	$1.16	$0.17
		Medium	$1.42	$0.13
Layer	MW/MA	All	$24.63	$16.98
Turkey	MW/MA	All	$20.08	$16.61
		Medium	$11.24	$6.47

Source: Data used for main analysis are USDA/ERS (1999a), derived on a per-animal basis by EPA. Data used for sensitivity analysis are derived from the data in the main analysis, with USEPA assumptions (uses the USDA-reported livestock portion of total farm revenue only and disregards revenue from other farm-related sources, including crops). Table 4-1 defines regions and facility size.

Table D-4. Number of CAFOs Affected Assuming Alternative Assumption (Livestock Revenues Only)

Sector	No. of CAFOs	Scenario 4b–Sensitivity Analysis			Scenario 4b–Main Analysis		
		Aff.	Mod.	Stress	Aff.	Mod.	Stress
		(number)			(number)		
Fed Cattle	4,070	2,140	1,450	490	2,880	1,150	40
Veal	210	210	0	0	210	0	0
Heifer	1,050	630	250	170	850	150	50
Dairy	7,140	5,770	670	700	6,010	440	700
Hogs (Zero CPT)	14,370	9,950	1,400	3,020	12,710	240	1,420
Hogs (Partial CPT)	14,370	12,960	1,410	0	14,370	0	0
Broilers (Zero CPT)	14,140	0	0	14,140	1,960	11,860	320
Broilers (Partial CPT)	14,140	0	0	14,140	12,690	1,450	0
Layers - Wet	360	360	0	0	360	0	0
Layers - Dry	1,700	1,700	0	0	1,700	0	0
Turkeys	2,100	1,990	10	100	1,990	110	0
Total (Zero CPT)	45,140	22,750	3,780	18,610	28,680	13,950	2,520
Total (Partial CPT)	45,140	25,760	3,790	15,600	41,070	3,300	790
Total (excl. broilers) (Partial CPT)	**45,140**	**25,760**	**3,790**	**1,450**	**28,380**	**1,850**	**790**

Source: USEPA. Numbers may not add due to rounding.
Evaluated for the BAT Option and Scenario 4b (Options/Scenarios are defined in Table 3-1). Category definitions (“Affordable,” “Moderate” and “Stress”) are provided in Table 4-13.

D.1.3 Sales Test Sensitivity (Pre-tax Compliance Cost Assumption)

The sensitivity analysis described in this appendix section assesses a change in methodology, not a change in baseline assumptions. As described in Section 4, EPA's main analysis evaluates cost-to-sales ratios (among other criteria) using EPA's estimated compliance costs for model facilities adjusted for expected tax savings (i.e., evaluating impacts using post-tax costs). An alternative approach would be to evaluate cost impacts before taxes (i.e., using pre-tax costs). Although EPA believes that pre-tax costs fail to reflect actual bottom-line impacts at a facility, EPA conducts this sensitivity analysis to examine whether the results of the analysis would differ substantially if pre-tax costs were used in the analysis.

Data inputs to this sensitivity analysis on an annual, pre-tax, per-head basis are not reproduced here, but can be found in the rulemaking record (DCN 70601). For comparison, EPA presents the post-tax costs in Appendix A. The equivalent after-tax cost is approximately 60 to 70 percent of the pre-tax cost.

Table D-5 compares the results of EPA's sensitivity analysis to the results of the main analysis. Under a zero CPT assumption, the percentage of CAFOs expected to experience financial stress increases from 5.5 percent to 13.9 percent of all CAFOs in the sensitivity analysis. More CAFOs are estimated to experience financial stress in the fed cattle, heifer, hog, and broiler sectors in the sensitivity analysis. Under a partial CPT assumption, an additional 270 CAFOs (1,060 CAFOs versus 790 CAFOs) are estimated to experience financial stress compared to the main analysis. As in the main analysis, no hog or broiler operations are expected to experience financial stress under a partial CPT assumption. The percentage of operations experiencing financial stress assuming partial CPT increases from 1.7 percent (main analysis) to 2.3 percent (sensitivity analysis) of all CAFOs. Based on the results of this sensitivity analysis, EPA would likely not change the proposal made in the main analysis that the proposed CAFO regulations would be economically achievable.

D.1.4 Discounted Cash Flow Analysis (Lower Net Cash Income)

The sensitivity analysis described in this appendix section assesses EPA assumptions of the baseline conditions as they affect the results of EPA's discounted cash flow analysis. EPA's main analysis evaluates impacts using net cash farm income from the 1997 ARMS data provided by USDA and derived by EPA on a per-animal basis using available data from ARMS that correspond to the financial data (described in Section 4). These data are average and may not reflect conditions at some operations that may generate net cash income below the national average (e.g., due to higher-cost, less efficient production).

To evaluate the baseline assumptions on net cash income and to account for differences in net returns among producers, EPA modifies the baseline data used in the main analysis by adding 5 percent to the USDA-reported variable costs and then re-calculating net cash income, assuming that gross farm revenues and fixed costs remain the same. A similar approach was used by DPRA (1995), wherein published average data from USDA were used estimate net cash income for animal feeding operations by characterizing vulnerable operations from the average by increasing the estimated average totals cost per facility by 5 percent and favorable operations by decreasing total cost per facility by 5 percent. Table D-6 presents a comparison of net cash income used in the main analysis and the modified returns used in this sensitivity analysis (expressed on a per-animal basis).

Table D-5. Number of CAFOs Affected Assuming Alternative Assumption (Pre-Tax Costs)

Sector	No. of CAFOs	Scenario 4b–Sensitivity Analysis			Scenario 4b–Main Analysis		
		Aff.	Mod.	Stress	Aff.	Mod.	Stress
		(number)			(number)		
Fed Cattle	4,070	2,180	1,610	280	2,880	1,150	40
Veal	210	210	0	0	210	0	0
Heifer	1,050	690	270	80	850	150	50
Dairy	7,140	5,430	1,010	700	6,010	440	700
Hogs (Zero CPT)	14,370	9,430	1,190	3,750	12,710	240	1,420
Hogs (Partial CPT)	14,370	14,070	300	0	14,370	0	0
Broilers (Zero CPT)	14,140	0	12,690	1,450	1,960	11,860	320
Broilers (Partial CPT)	14,140	7,000	7,140	0	12,690	1,450	0
Layers - Wet	360	360	0	0	360	0	0
Layers - Dry	1,700	1,700	0	0	1,700	0	0
Turkeys	2,100	1,990	110	0	1,990	110	0
Total (Zero CPT)	45,140	22,000	16,890	6,260	28,680	13,950	2,520
Total (Partial CPT)	**45,140**	**33,640**	**10,450**	**1,060**	**41,070**	**3,300**	**790**

Source: USEPA. Numbers may not add due to rounding.
Evaluated for the BAT Option and Scenario 4b (Options/Scenarios are defined in Table 3-1). Category definitions (“Affordable,” “Moderate” and “Stress”) are provided in Table 4-13.

Table D-6. Baseline Net Cash Income in Main Analysis and Sensitivity Analysis (Lower Net Cash Income)

Sector	Region	Facility Size Grouping	Main Analysis Cash Income/Head	Sensitivity Analysis Cash Income/Head
Beef	MW	Large	$256.28	$232.28
		Medium	$79.37	$62.59
	CE	Large	$321.83	$299.88
		Medium	$80.71	$66.21
Dairy	MW	Large	$435.17	$336.00
		Medium	$443.71	$358.22
		Small	$598.06	$518.48
	PA	Large	$401.74	$302.36
		Medium	$224.73	$129.55
Hog	MA	Large	$31.16	$29.06
		Medium	$30.64	$24.79
	MW	Large	$46.51	$38.68
		Medium	$66.02	$56.33
		Small	$118.64	$100.38
Broiler	MA	Large	$0.48	$0.46
		Medium	$0.57	$0.54
	SO	Large	$0.49	$0.47
		Medium	$0.57	$0.54
Layer	MW/MA	All	$4.06	$3.22
Turkey	MW/MA	All	$1.77	$0.90
		Medium	$2.55	$2.19

Source: Data used for main analysis are USDA/ERS (1999a), derived on a per-animal basis by EPA. Data used for sensitivity analysis are derived from the data in the main analysis, with USEPA assumptions (adjusts the USDA-reported variable costs upward by 5 percent and re-calculates net cash income, assuming all other costs remain constant). Table 4-1 defines regions and facility size.

Table D-7 compares the results of EPA's sensitivity analysis to the results of the main analysis. Under a zero CPT assumption, the percentage of CAFOs experiencing financial stress increases from 5.6 percent in the main analysis to 7.3 percent of all CAFOs in the sensitivity analysis. More CAFOs are estimated to experience financial stress in the fed cattle and dairy sectors in the sensitivity analysis. Under a partial CPT assumption, an additional 770 CAFOs (1,560 CAFOs versus 790 CAFOs) are estimated to experience financial stress compared to the main analysis. As in the main analysis, no hog or broiler operations are expected to experience financial stress under a partial CPT assumption. The percentage of operations experiencing financial stress assuming partial CPT increases from 1.7 percent (main analysis) to 3.4 percent (sensitivity analysis) of all CAFOs. Based on the results of this sensitivity analysis, EPA would likely not change the proposal made in the main analysis that the proposed CAFO regulations would be economically achievable.

D.1.5 Debt-to-Asset Analysis (Higher Debt-to-Asset Levels)

The sensitivity analysis described in this appendix section assesses EPA assumptions of the baseline conditions as they affect the results of EPA's financial ratio analysis. EPA's main analysis evaluates impacts using debt-to-asset ratios from the 1997 ARMS data provided by USDA. These data are average and may not reflect conditions at some operations that face higher financial risk (e.g., due to higher debt levels relative to assets at some farms).

To evaluate the baseline assumptions and to account for differences in debt-to-asset levels among producers, EPA modifies the baseline data used in the main analysis by adjusting the USDA-reported baseline values upward. For this analysis, EPA re-calculates these ratios by reducing asset levels by a fixed amount without changing the reported debt levels. (Although the adjustment is made on the basis of assets, the same result could have been achieved using alternative debt assumptions to reflect higher debt levels at some operations.[3])

Analyses of USDA's Census data by Letson and Gollehon (1996) and Gollehon and Caswell (2000) show that larger livestock and poultry farms have less land devoted to non-livestock purposes than smaller farms. To conduct a simple sensitivity test, EPA assumes that CAFOs with less land may have higher debt due to lower asset levels.[4] For this sensitivity analysis, EPA adjusts the USDA-reported debt-to-asset ratios at Category 2 and Category 3 CAFOs.[5] At Category 3 CAFOs among the larger-sized operations with more than 1,000 AU,

[3]For example, Stott (2000b) has noted that feedlots generally maintain a higher level of debt than cow-calf operations that are represented by the ARMS data used for this analysis to examine impacts to the beef sector.

[4]However, it is also possible that operations with less land have less debt on average (e.g., the additional land at CAFOs with sufficient land for land application might be mortgaged).

[5]EPA's model CAFOs are divided into three land availability types: CAFOs with sufficient land for land application of manures (Category 1), CAFOs with insufficient land for land application of manures (Category 2), and CAFOs with no land for land application of manures (Category 3).

Table D-7. Number of CAFOs Affected Assuming Alternative Assumption (Lower Net Cash Income)

Sector	No. of CAFOs [a/]	Scenario 4b–Sensitivity Analysis			Scenario 4b–Main Analysis		
		Aff.	Mod.	Stress	Aff.	Mod.	Stress
		(number)			(number)		
Fed Cattle	4,070	2,870	950	260	2,880	1,150	40
Veal	210	210	0	0	210	0	0
Heifer	1,050	850	150	50	850	150	50
Dairy	7,140	5,620	260	1,250	6,010	440	700
Hogs (Zero CPT)	14,370	12,710	240	1,420	12,710	240	1,420
Hogs (Partial CPT)	14,370	14,370	0	0	14,370	0	0
Broilers (Zero CPT)	14,140	1,960	11,860	320	1,960	11,860	320
Broilers (Partial CPT)	14,140	12,690	1,450	0	12,690	1,450	0
Layers - Wet	360	360	0	0	360	0	0
Layers - Dry	1,700	1,700	0	0	1,700	0	0
Turkeys	2,100	1,990	110	0	1,990	110	0
Total (Zero CPT)	**45,140**	**28,270**	**13,580**	**3,290**	**28,680**	**13,950**	**2,520**
Total (Partial CPT)	**45,140**	**40,660**	**2,930**	**1,560**	**41,070**	**3,300**	**790**

Source: USEPA. Numbers may not add due to rounding.
Evaluated for the BAT Option and Scenario 4b (Options/Scenarios are defined in Table 3-1). Category definitions (“Affordable,” “Moderate” and “Stress”) are provided in Table 4-13.

EPA adjusts asset levels downward by 15 percent at poultry operations and by 25 percent at other livestock operations. No adjustments are made on the reported data for larger Category 2 CAFOs, which are assumed to represent the average land availability category for larger facilities. Among medium-sized operations with between 300 and 1,000 AU, EPA adjusts asset levels downward by 5 percent at poultry operations and by 10 percent at other livestock operations at Category 2 CAFOs. At Category 3 medium-sized operations, EPA adjusts asset levels downward by 10 percent at poultry operations and by 20 percent at other livestock operations. Variability of assets is expected to be greater among the livestock sectors than among the poultry sectors because of the greater land requirements in general for livestock production compared to poultry production. No adjustments are made to data assumed for the smaller-sized operations with less than 300 AU.

Table D-8 presents a comparison of the debt-to-asset levels used in the main analysis and the modified revenues used in this sensitivity analysis. As shown, these higher debt-to asset ratios result in all large hog model CAFOs (Category 3) for both the Mid-Atlantic and Midwest regions to become identified as financially vulnerable in the baseline. These models would typically not be analyzed as part of a regulatory impact analysis since these operations are already assumed to close in the pre-regulatory baseline. For this sensitivity analysis, however, EPA continues to include these operations in the impact analysis. The remaining CAFOs represented by all other models are considered to be financially healthy in the baseline.

Table D-9 compares the results of EPA's sensitivity analysis to the results of the main analysis. Under a zero CPT assumption, the percentage of operations experiencing financial stress increases from 5.6 percent (main analysis) to 6.4 percent (sensitivity analysis) of all CAFOs. More CAFOs are estimated to experience financial stress in the broiler sector only, resulting in an additional 380 operations estimated to be vulnerable to closure as a result of compliance. Under a partial cost passthrough assumption, no broilers or hogs are expected to experience financial stress in either the main analysis or the sensitivity analysis. Under partial cost passthrough, the results of this sensitivity analysis and the main analysis are identical. Based on the results of this sensitivity analysis, EPA would likely not change the proposal made in the main analysis that the proposed CAFO regulations would be economically achievable. (For comparison purposes, EPA includes expected baseline closures in the hog sector (Category 3 large hog CAFOs). Excluding these operations would result in fewer operations considered potential closures, as compared to the main analysis, estimated at 810 fewer operations, as shown in Table D-9.)

D.2 MARKET MODEL SENSITIVITY ANALYSIS

To examine the stability of the results of EPA's market model results, EPA conducts various sensitivity analyses that examine the results of EPA's analysis under differing baseline value assumptions only. For this analysis, EPA examines alternative values for the baseline price elasticity and also market price.

Table D-8. Baseline Debt-to-Asset Ratios in Main Analysis and Sensitivity Analysis (Higher Debt-to-Assets)

Sector	Region	Size (Proxy)	Main Analysis Debt-to-Assets/Farm	Sensitivity Analysis Debt-to-Assets/Farm	
				Cat. 2	Cat. 3
Beef	MW	Large	0.09	0.09	0.12
		Medium	0.13	0.15	0.17
	CE	Large	0.09	0.09	0.12
		Medium	0.17	0.19	0.21
Dairy	MW	Large	0.26	0.26	0.35
		Medium	0.23	0.25	0.28
		Small	0.20	NA	NA
	PA	Large	0.24	0.24	0.32
		Medium	0.23	0.26	0.29
Hog	MA	Large	0.31	0.31	0.41
		Medium	0.13	0.14	0.16
	MW	Large	0.40	0.40	0.54
		Medium	0.25	0.28	0.31
		Small	0.17	NA	NA
Broiler	MA	Large	0.30	0.30	0.34
		Medium	0.21	0.22	0.23
	SO	Large	0.26	0.26	0.29
		Medium	0.19	0.20	0.21
Layer	MW/SO	All	0.11	0.11	0.12
Turkey	MW/MA	All	0.15	0.16	0.17
		Medium	0.23	0.23	0.26

Source: Data used for main analysis are USDA/ERS (1999a). Data used for sensitivity analysis are derived from USDA/ERS, 1999a, with USEPA assumptions (adjusts the USDA-reported debt-to-asset ratios upward for selected model CAFOs). Table 4-1 defines regions and facility size. NA= Not Applicable.

Table D-9. Number of CAFOs Affected Assuming Alternative Assumption (Higher Debt-to-Asset Ratios)

Sector	No. of CAFOs	Scenario 4b–Sensitivity Analysis			Scenario 4b–Main Analysis		
		Aff.	Mod.	Stress	Aff.	Mod.	Stress
		(number)			(number)		
Fed Cattle	4,070	2,870	1,160	40	2,880	1,150	40
Veal	210	210	0	0	210	0	0
Heifer	1,050	850	150	50	850	150	50
Dairy	7,140	5,810	640	700	6,010	440	700
Hogs (Zero CPT)	14,370	12,710	240	1,420	12,710	240	1,420
Hogs (Partial CPT)	14,370	14,370	0	0	14,370	0	0
Broilers (Zero CPT)	14,140	1,910	11,530	700	1,960	11,860	320
Broilers (Partial CPT)	14,149	12,690	1,450	0	12,690	1,450	0
Layers - Wet	360	360	0	0	360	0	0
Layers - Dry	1,700	1,700	0	0	1,700	0	0
Turkeys	2,100	1,990	110	0	1,990	110	0
Total (Zero CPT)	45,140	28,400	13,840	2,910	28,680	13,950	2,520
Total (excl. hog pre-reg closures) (Zero CPT)	**45,140**	**28,400**	**13,840**	**2,100**	**28,680**	**13,950**	**1,710**
Total (Partial CPT)	**45,140**	**40,840**	**3,520**	**790**	**41,070**	**3,300**	**790**

Source: USEPA. Numbers may not add due to rounding.
Evaluated for the BAT Option and Scenario 4b (Options/Scenarios are defined in Table 3-1). Category definitions ("Affordable," "Moderate" and "Stress") are provided in Table 4-13.

EPA has reviewed a wide range of price elasticity values for livestock and poultry products that are reported in the academic literature (see Appendix C). EPA realizes that the elasticity values selected for the market model, while carefully considered, are not the only possible set of realistic values. Therefore, EPA conducts a sensitivity analysis with several alternative sets of elasticities to assess whether the outcome would have been substantially different had different input elasticities been used. The analysis indicates that although the results would have differed, they would have been within the same order of magnitude as those generated in the main analysis.

EPA also investigates the effect that the baseline prices have on the analysis. The baseline prices that EPA uses for this analysis are 1997 averages, which may not reflect regional differences or different stages in the animal marketing cycle. (The attachment at the end of this appendix provides a summary of the key market data, including prices, for these sectors from 1992 to 2000 where available.) To test the impact of alternate price assumptions, different prices are substituted into the model. The results indicate that the price assumptions in the main analysis have little effect on predicted model outcomes.

D.2.1 Price Elasticities

For the main analysis EPA refers to elasticities reported in the academic literature and uses a "selected value" that generally reflects the approximate mid-range value or a value chosen based on best professional judgement (Table 4-14). For this sensitivity analysis, EPA investigates eight different alternative combinations of elasticities to test the sensitivity of the results to different model input. The eight combinations include the extremes of supply and demand elasticities found in the literature. Four combinations show the effect of changing each supply and demand elasticity to its most elastic or inelastic value while all other elasticities remain at their selected values. EPA also constructs minimum and maximum partial CPT estimates by applying an approach described in Section 4.2.6. This approach allows EPA to evaluate the results of the main analysis using combinations of supply and demand elasticities that minimize or maximize CPT within the market model.

EPA also investigates the effect of varying trade elasticity assumptions. The trade combinations test the influence of import and export assumptions on the results. The eight combinations of elasticities are shown in Table D-10. The actual elasticities used can be found in Table 4-14 (selected values) and Table B-1 (minimum and maximum values).

Table D-11 shows the range of farm product price results derived from changing the elasticity assumptions to evaluate the compliance costs of the proposed BAT Option in the model. The main analysis value shows the predicted change in farm product price under a post-regulatory scenario using the selected elasticity values presented in Table 4-14. The range of results is quite small in all sectors. The sensitivity analysis results are expressed as a range: the "low" value shown is the lowest farm product price and the "high" value shown is the highest farm product price derived from any of the sets of alternative elasticity assumptions. Lower predicted prices result from the minimum CPT assumptions, while most of the high-end predicted prices result from the maximum CPT assumptions. Since the predicted changes in farm product prices are small, the corresponding changes in retail product prices are even less and are not presented here.

Table D-12 shows the changes in total employment that result from alternative elasticity assumptions. The main analysis value corresponds to the market model results presented in Section 5.4. Although the ranges shown for the sensitivity analysis may appear sizable, they are

Table D-10. Elasticity Sensitivity Test Sets

Set Name	Elasticity of Supply	Elasticity of Demand	Trade Elasticities
Inelastic Supply	Minimum from Table B-1	Selected	Selected
Elastic Supply	4	Selected	Selected
Inelastic Trade	Selected	Selected	0
Elastic Trade	Selected	Selected	4
Inelastic Demand	Selected	Maximum from Table B-1	Selected
Elastic Demand	Selected	Minimum from Table B-1	Selected
Max CPT	4	Maximum from Table B-1	Selected
Min CPT	Minimum from Table B-1	Minimum from Table B-1	Selected

Source: USEPA. CPT= Cost passthrough. "Selected" indicates the selected elasticity value shown in Table 4-14. Alternative values (minimums and maximums) can be seen in Table B-1.

Table D-11. Range of Postregulatory Farm Product Price Results with Different Elasticity Assumptions

Sector	Units	Farm Product Price		
		Main Analysis Value	Low Value [a/]	High Value [b/]
Beef	$/cwt	66.30	66.11	66.37
Dairy	$/cwt	13.44	13.39	13.45
Hog	$/cwt	54.89	54.32	55.13
Broiler	cents/lb.	37.19	37.05	37.57
Layer	cents/doz.	69.93	69.81	69.95
Turkey	cents/lb.	40.22	40.21	40.34

Source: USEPA.
[a/] All low values are generated by assuming minimum CPT.
[b/]All high values shown are generated assuming maximum CPT except for broilers and layers, in which the elastic import/export assumption generated the high value shown.

not large in terms of the percentages of sector employment they represent. Also, the width of the ranges shown varies with the magnitude of compliance costs estimated for each sector. EPA estimates that costs to the hog sector account for the majority of the total incremental costs of the rule and therefore show the widest range of predicted employment loss. EPA estimates that the poultry sector will incur lower costs and therefore fewer employment losses. The losses estimated in the main analysis are more similar to the high-end value of the estimated ranges shown for most sectors (Table D-12).

Based on the results of this sensitivity analysis, EPA would likely not change the proposal made in the main analysis that the proposed CAFO regulations would be economically achievable.

Table D-12. Range of Total Employment Change Results with Different Elasticity Assumptions

Sector	Main Analysis Value	Sensitivity Analysis Value	
		Low Value [a/]	High Value [b/]
	(FTE losses)		
Beef	4,599	1,876	5,397
Dairy	3,200	2,753	3,816
Hog	6,376	1,388	7,332
Broiler	1,865	1,404	2,265
Layer	202	184	292
Turkey	373	357	415

Source: USEPA.
[a/] Low values for beef and dairy are generated by assuming inelastic supply. Low values for layer and turkey are generated by assuming inelastic demand. Minimum CPT and elastic imports and exports generate hog and broiler low values, respectively.
[b/]All high values shown are generated by assuming elastic demand except for hog and turkey in which the elastic supply assumption generated the high value shown.

D.2.2 Prices

In addition to the price elasticities, the market model results also depend on baseline price and quantities as input values to the model. Table D-13 shows the effects of raising or lowering the baseline farm and retail prices used in the main analysis by 50 percent. The main analysis value shows the predicted change in farm and retail prices under a post-regulatory scenario when the baseline values assume the selected levels presented in Table 4-16 (baseline prices). The farm and retail price range shown in Table D-13 indicate the range of predicted prices in the sensitivity analysis when the baseline prices are raised or lowered by 50 percent.

As shown in Table D-13, hog farm prices show the widest range of change in farm product prices, but even the ranges for this sector are fairly narrow. This analysis demonstrates that even if baseline prices are assumed to vary +/-50 percent, this would not substantially change the results of EPA's market model.

Table D-13. Range of Price Changes with Different Baseline Price Assumptions

Sector	Baseline Price Main Analysis	Units	Main Analysis Change	Sensitivity Analysis Value	
				Farm Price Range	Retail Price Range
Change in Farm Product Prices					
Beef	66.09	$/cwt	0.21	0.19-0.24	0.17-0.23
Dairy	13.38	$/cwt	0.06	0.06-0.07	0.05-0.06
Hog	54.30	$/cwt	0.59	0.52-0.68	0.46-0.65
Broiler	37	cents/lb.	0.19	0.16-0.22	0.14-0.21
Layer	40	cents/dozen	0.13	0.13-0.14	0.12-0.13
Turkey	70	cents/lb.	0.12	0.10-0.16	0.08-0.15
Change in Retail Prices					
Beef	2.80	$/lb.	0.00	0.00-0.00	0.00-0.00
Dairy	145.5	Index	0.61	0.56-0.66	0.53-0.64
Hog	2.45	$/lb.	0.01	0.01-0.01	0.01-0.01
Broiler	151	cents/lb.	0.19	0.16-0.22	0.14-0.21
Layer	106	cents/dozen	0.13	0.13-0.14	0.12-0.13
Turkey	105	cents/lb.	0.12	0.10-0.16	0.08-0.15

Source: USEPA. Low and high values are created assuming that baseline prices are 50 percent lower or higher than the baseline prices used in the main analysis.

Attachment 1. Key Annual Statistics by Sector, 1992-2000

	1992	1993	1994	1995	1996	1997	1998	1999	2000F[m]	Average
Corn ($/Bu) [a]	$2.07	$2.50	$2.26	$3.24	$2.71	$2.45	$1.95	$1.90	NA	$2.39
Beef Feedlot Sector										
Beef cattle farm-level price ($/cwt, all beef) [b]	$71.30	$72.60	$66.70	$61.80	$58.70	$63.10	$59.60	$63.25	NA	$64.63
Beef cattle feed price ($/ton, 32-36% protein) [c]	$249	$261	$275	$251	$316	$325	$292	NA	NA	$281
Beef cattle production (million lbs. carcass) [d]	23,086	23,049	24,386	25,222	25,525	25,384	25,653	26,390	25,700	24,933
Commercial cattle slaughter (1,000 head) [e]	32,873	33,325	34,196	35,639	36,577	36,318	35,465	36,160	NA	35,069
Cow-calf operation total value of production ($/cow) [f]	$413.56	$430.18	$389.21	$331.92	$318.18	$414.27	$402.98	NA	NA	$385.76
Cow-calf operation net cash income ($/cow) [g]	$31.11	$15.28	($22.86)	($78.73)	($112.33)	($30.46)	($2.99)	NA	NA	($28.71)
Choice beef farm-retail price spread (cents, 1982-84=100) [h]	122.8	129.3	137.4	147.2	145.3	142.3	139.9	157	NA	NA
Producer price index (beef and veal, 1982=100) [I]	109.5	112.9	103.6	100.9	100.2	102.8	99.5	106.3	NA	NA
Consumer price index (beef and veal, 1982-84=100) [j]	132.3	137.1	136.0	134.9	134.5	136.8	136.5	139.2	142.0	NA

Attachment 1. Key Annual Statistics by Sector, 1992-2000

	1992	1993	1994	1995	1996	1997	1998	1999	2000F[m]	Average
Veal Sector										
Farm-level price ($/cwt calves) [b]	$89.00	$91.20	$87.20	$73.10	$58.40	$78.90	$78.80	$89.56	NA	$80.77
Veal production (million lbs. veal) [d]	310	285	293	319	378	334	262	237	222	293
Calf slaughter (1,000 head) [e]	1,372	1,195	1,268	1,430	1,767	1,575	1,458	1,484	NA	1,444
Producer price index (beef and veal, 1982=100) [I]	109.5	112.9	103.6	100.9	100.2	102.8	99.5	106.3	NA	NA
Consumer price index (beef and veal, 1982-84=100) [j]	132.3	137.1	136.0	134.9	134.5	136.8	136.5	139.2	142.0	NA
Dairy Farm Sector										
All milk price (delivered to plants and dealers, $/cwt) [b]	$13.09	$12.80	$12.97	$12.74	$14.74	$13.34	$15.42	$14.38	$12.55	$13.56
Dairy feed price ($/ton, 32% protein conc) [c]	$279	$285	$304	$276	$333	$362	$302	NA	NA	$306
Milk production (billion lbs., milkfat basis)[b]	150.9	150.6	153.6	155.3	154.0	156.1	157.4	162.7	165.5	156.2
Dairy farm total value of production ($/cwt) [f]	$14.58	$14.35	$14.50	$14.27	$16.17	$14.87	$16.89	NA	NA	$15.09
Dairy farm net cash income ($/cwt) [g]	$4.44	$1.99	$1.60	$1.76	$2.97	$0.65	$3.42	NA	NA	$2.40
Dairy products farm-retail price spread (cents, 1982-84=100) [h]	158.6	162.9	166.1	170.3	174.3	189.3	185.6	207.1	NA	NA
Producer price index (dairy products, 1982=100) [I]	117.9	118.1	119.5	119.7	130.4	128.1	138.1	139.5	NA	NA
Consumer price index (dairy products-incl. butter, 1982-84=100) [j]	128.5	129.4	131.7	132.8	142.1	145.5	150.8	159.6	157.0	NA

Attachment 1. Key Annual Statistics by Sector, 1992-2000

	1992	1993	1994	1995	1996	1997	1998	1999	$2000F_m$	Average
Hog Sector										
Barrow & gilt price ($/cwt,) b	$42.40	$45.90	$40.60	$41.20	$52.70	$53.50	$35.00	$30.80	NA	$42.76
Sow price ($/cwt) b	$32.77	$35.82	$30.51	$30.97	$42.69	$42.97	$23.24	$23.36	NA	$32.79
All hog price ($/cwt, all hogs) b	$41.60	$45.20	$39.90	$40.50	$51.90	$52.90	$34.40	$34.47	NA	$42.61
Hog feed price ($/ton, 38-42% protein conc.) c	$304	$305	$317	$292	$351	$389	$317	NA	NA	$325
Pork production (million lbs. pork carcass) d	17,234	17,088	17,696	17,849	17,117	17,274	19,011	19,308	18,630	17,912
Hog slaughter (1,000 head, hogs, bar./gils) e	94,888	93,069	95,697	96,326	92,397	91,960	101,029	101,555	NA	95,865
Hog farm total value of production ($/cwt gain) f	$48.49	$54.53	$46.80	$48.37	$60.16	$63.25	$39.36	NA	NA	$51.57
Hog farm net cash income ($/cwt gain) g	$6.65	$10.02	$3.38	$4.35	$7.03	$11.70	($5.85)	NA	NA	$5.33
Pork farm-retail price spread (cents, 1982-84=100) h	130.2	125.1	135.1	128.1	136.3	149.7	181.5	181.1	NA	NA
Producer price index (pork, 1982=100) I	98.9	105.7	101.3	101.4	120.9	123.1	96.6	95.7	NA	NA
Consumer price index (pork, 1982-84=100) j	127.8	131.7	133.9	134.8	148.2	155.9	148.5	145.9	149.0	NA

Attachment 1. Key Annual Statistics by Sector, 1992-2000

	1992	1993	1994	1995	1996	1997	1998	1999	2000F[m]	Average
Broiler Sector										
Broiler price received (cents/lb.) [b]	31.85	34.43	34.95	34.66	38.46	36.95	39.85	NA	NA	35.88
Broiler grower feed price ($/ton) [c]	$125.40	$131.40	$136.40	$139.30	$175.10	$157.70	$128.70	$102.45	NA	$137.06
Broiler and chicken meat production (million lbs.) [d]	21,423	22,530	24,175	25,323	26,615	27,551	28,137	29,968	31,425	26,350
Chicken slaughter (thousand head) [e]	6,602,337	6,856,901	7,239,595	7,530,847	7,699,858	7,903,539	8,006,980	8,287,215	NA	7,515,909
Broiler farm costs (cents/lb) [k]	26.7	26.4	27.2	26.4	31.7	29.6	26.3	24.4	NA	27.34
Broiler farm net returns (cents/lb) [l]	5.2	8.0	7.8	8.3	6.8	7.4	13.6	NA	NA	8.2
Poultry farm-retail price spread (cents, 1982-84=100) [h]	163.0	166.2	172.6	177.7	182.6	198.1	192.9	202.7	NA	NA
Producer price index (processed poultry, 1982=100) [I]	109.0	111.7	114.8	114.3	119.8	117.4	120.7	114.0	NA	NA
Consumer price index (poultry, 1982-84=100) [j]	131.4	136.9	141.5	143.5	152.4	156.6	157.1	157.9	158.0	NA
Turkey Sector										
Turkey prices received (cents/lb) [b]	37.63	38.99	40.74	41.08	43.48	40.10	37.88	NA	NA	39.99
Turkey grower feed price ($/ton) [c]	$117.30	$118.80	$125.50	$130.10	$165.80	$142.70	$115.70	$93.86	NA	$126.22
Turkey production (million lbs. carcass) [d]	4,777	4,798	4,937	5,069	5,401	5,412	5,215	5,230	5,332	5,130
Turkey slaughter (1,000 head) [e]	281,404	276,257	278,912	281,032	293,290	290,230	273,013	265,250	NA	279,924
Turkey farm costs (cents/lb) [k]	36.9	36.1	37.7	35.6	45.3	41.9	36.7	32.7	NA	37.9
Turkey farm returns (cents/lb) [l]	0.8	2.9	3.1	5.4	-1.8	-1.8	1.2	NA	NA	1.4

Attachment 1. Key Annual Statistics by Sector, 1992-2000

	1992	1993	1994	1995	1996	1997	1998	1999	2000F m	Average
Poultry farm-retail price spread (cents, 1982-84=100) h	163.0	166.2	172.6	177.7	182.6	198.1	192.9	202.7	NA	NA
Producer price index (processed poultry, 1982=100) I	109.0	111.7	114.8	114.3	119.8	117.4	120.7	114.0	NA	NA
Consumer price index (poultry, 1982-84=100) j	131.4	136.9	141.5	143.5	152.4	156.6	157.1	157.9	158.0	NA
Layer Sector										
Egg price (cents/dozen eggs, table eggs excluding hatching eggs) b	45.00	51.34	49.20	50.36	64.33	58.73	52.56	NA	NA	53.07
Laying feed price ($/ton) c	$200	$201	$215	$195	$258	$251	$224	NA	NA	$221
Egg production (million dozen) d	5,905	6,006	6,178	6,216	6,351	6,473	6,658	6,911	7,080	6,420
Layer farm costs (cents/dozen) k	46.2	46.0	47.1	47.0	57.7	51.6	45.2	41.9	NA	47.84
Layer farm net returns (cents/dozen) l	-1.2	5.4	2.1	3.4	6.6	7.1	7.4	NA	NA	4.4
Eggs farm-retail price spread (cents, 1982-84=100) h	163.2	167.8	169.4	173.2	191.4	213.0	222.5	223.7	NA	NA
Producer price index (chicken eggs, 1982=100) I	94.1	105.9	97.8	104.1	130.7	119.0	107.6	89.4 (P)	NA	NA
Consumer price index (eggs, 1982-84=100) j	108.3	117.1	114.3	120.5	142.1	140.0	135.4	128.1	126.0	NA

NA = Not available. F = Forecast. P = Preliminary.
Sources:

Attachment 1. Key Annual Statistics by Sector, 1992-2000 (continued)

Sources:

[a] USDA, NASS. Agricultural Prices Annual Summary. Various years.

[b] USDA, NASS. Agricultural Prices. Received via email from Greg Thessen, USDA, NASS, regarding livestock prices received by farmers (1992-1996).

[c] USDA, NASS. 1998. Agricultural Prices, 1997 Summary. July.

[d] USDA, ERS, Food Consumption, Prices, and Expenditures, 1970-1995. August 1997.

[e] Red Meat Yearbook. Beef, hog, and veal slaughter (1992 and 1993):

[f,g] USDA, ERS, Farm Sector Performance- Situation and Outlook.

[h] USDA, ERS, Agricultural Outlook, various years. Key Statistical Indicators. Farm-retail Price Spreads (Table 8).

[i] Bureau of Labor Statistics Data. Producer Price Index-Commodities.

[j] Bureau of Labor Statistics Data. Consumer Price Index-All Urban Consumers.

[k] USDA, NASS. Poultry Yearbook

[l] Broiler, Layer, and Turkey Farm Returns calculated by subtracting Farm Costs from Farm Prices.

[m] 2000 Forecasts: USDA Agricultural Baseline Projections to 2009.

APPENDIX E

COST-EFFECTIVENESS ANALYSIS

As part of the process of setting effluent limitations guidelines and developing standards, EPA uses cost-effectiveness calculations to compare the efficiencies of regulatory options for removing priority and non-conventional pollutants.[1] Although not required by the Clean Water Act, a cost-effectiveness (C-E) analysis offers a useful metric to compare the efficiency of alternative regulatory options in removing pollutants and to compare the proposed technology option to other regulatory alternatives that were considered by EPA.

For the purpose of this regulatory analysis, EPA defines cost-effectiveness as the incremental annualized cost of a technology option per incremental pound of pollutant removed annually by that option.[2] The analyses presented in this section include a standard cost-effectiveness (C-E) analysis, based on the approach EPA has historically used for developing an effluent guideline for toxic pollutants, but also expands on this approach to include an analysis of the cost-effectiveness of removing nutrients and sediments. This expanded approach is necessary to evaluate the broad range of pollutants in animal manure and wastewater, which include metallic compounds, nutrients, total suspended solids, and pathogens. Of these pollutants, EPA's standard C-E analysis is suitable for analyzing only the removal of toxic pollutants. EPA's standard C-E analysis does not adequately address removals of nutrients, total suspended solids, and pathogens. To account for the estimated removals of nutrients and sediments under the proposed CAFO regulations in the analysis, the Agency has developed an alternative approach to evaluate the pollutant removal effectiveness relative to cost. At this time, EPA has not developed an approach that would allow a similar assessment of pathogen removals. Estimates of pathogen reductions in manure and wastewater discharged from CAFOs under the proposed regulations are provided in the *Development Document* (USEPA, 2000a).

The organization of this section is as follows. Section E.1 provides an introduction and describes the types and concentrations of pollutants found in animal manure and wastewater. Section E.2 summarizes EPA's estimated baseline loadings and removals of metals, nutrients, total suspended solids and pathogens from feedlot and land application areas, for selected

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[1]A list of priority ("toxic") and conventional pollutants are defined at 40 CFR Part 401. There are more than 120 priority pollutants, including metals, pesticides, and organic and inorganic compounds. Conventional pollutants include biological oxygen demand (BOD), total suspended solids (TSS), pH, fecal coliform, and oil and grease. Non-conventional pollutants comprise all other pollutants, including nutrients (i.e., they do not include conventional and priority pollutants).

[2]EPA defined cost-effectiveness similarly for Phase II of the Storm Water rule (USEPA, 1999f) and examined the incremental annualized cost of each pollution control option to the incremental pound of TSS removed annually.

regulatory alternatives. Section E.3 presents a standard C-E analysis and focuses on a subset of metallic compounds that are found in animal manure and wastewater. Section E.4 then presents an analysis of the-cost-effectiveness of loadings reductions of nutrients and total suspended solids. For this rule, EPA estimates the expected percentage reductions in pathogens from agricultural runoff but does not compare these removals to costs of the regulatory controls. Section E.5 concludes the section by presenting EPA's assessment of the overall effectiveness of the proposed combination of options to remove the pollutants of concern relative to the effectiveness of other options considered in these analyses.

More detail on the environmental damages associated with livestock and poultry operations and the pollutants in animal manure is provided in the *Environmental Assessment* (USEPA, 2000b) and the *Benefits Analysis* (USEPA, 2000d). Additional information on EPA's estimated loadings and removals under post-compliance conditions is provided in the *Development Document* (USEPA, 2000a) and also in the *Benefits Analysis* (USEPA, 2000d).

E.1 POLLUTANTS OF CONCERN

E.1.1 Introduction

Manure and wastewater from animal feeding operations have the potential to contribute pollutants such as nutrients (e.g., nitrogen and phosphorus), organic matter, sediments, pathogens, metals and metallic compounds, hormones, antibiotics, and ammonia to the environment (USEPA, 2000b; USDA and USEPA, 1999).   Additional information on the pollutants in animal manure and on water quality impairment and risks associated with manure discharge and runoff is provided in the Section V of the preamble and in the *Environmental Assessment* (USEPA, 2000b).

National and local studies confirm the presence of manure pollutants in U.S. waters. EPA's 1998 *National Water Quality Inventory* (USEPA, 2000h), prepared under section 305(b) of the Clean Water Act, presents information on impaired water bodies based on reports from the states. Agricultural operations—including animal feeding operations—are considered a significant source of water pollution in the United States (USEPA, 2000h). As shown in Table E-1, agriculture[3] is the leading contributor to identified water quality impairments in the nation's rivers and lakes and the fifth leading contributor to identified water quality impairments in the nation's estuaries (USEPA, 2000h).

Table E-1 also lists the leading pollutants that impair surface water quality in the United States, as identified in the *National Water Quality Inventory*. Livestock and poultry operations are a potential source of all of these, but are most commonly associated with nutrients, pathogens,

[3] Includes crop production, pastures, rangeland, feedlots, animal holding areas, other animal feeding operations, pasture and range grazing, concentrated and confined animal feeding operations, and aquaculture.

Table E-1. Leading Sources and Pollutants of Water Quality Impairment in the United States, 1998

Rank	Rivers & Streams	Lakes, Ponds, & Reservoirs	Estuaries
Sources [a/]			
1	Agriculture (59%)	Agriculture (31%)	Municipal Point Sources (28%)
2	Hydromodification (20%)	Hydromodification (15%)	Urban Runoff/Storm Sewers (28%)
3	Urban Runoff/Storm Sewers (11%)	Urban Runoff/Storm Sewers (12%)	Atmospheric Deposition (23%)
4	Municipal Point Sources (10%)	Municipal Point Sources (11%)	Industrial Discharges (15%)
5	Resource Extraction (9%)	Atmospheric Deposition (8%)	Agriculture (15%)
Pollutants [b/]			
1	Siltation (38%)	Nutrients (44%)	Pathogens (47%)
2	Pathogens (36%)	Metals (27%)	Oxygen-Depleting Substances (42%)
3	Nutrients (29%)	Siltation (15%)	Metals (27%)
4	Oxygen-Depleting Substances (23%)	Oxygen-Depleting Substances (14%)	Nutrients (23%)
5	Metals (21%)	Suspended Solids (10%)	Thermal Modifications (18%)

Source: USEPA, 2000h. Figure totals exceed 100 percent because water bodies may be impaired by more than one source or pollutant.
[a/]Fraction of impairment attributed to each source is shown in parentheses. For example, agriculture is listed as a source of impairment in 59 percent of impaired river miles. The portion of "agricultural" impairment attributable to animal waste (as compared to crop production, pasture grazing, range grazing, and aquaculture) is not specified.
[b/]Percent impairment attributed to each pollutant is shown in parentheses. For example, siltation is listed as a cause of impairment in 51 percent of impaired river miles.

oxygen-depleting substances, and solids (siltation). Animal operations are also a potential source of other leading causes of water quality impairment, such as metals and pesticides, and can contribute to the growth of noxious aquatic plants due to the discharge of excess nutrients. Animal operations may also contribute loadings of priority toxic organic chemicals and oil and grease, but most likely to a lesser extent than they contribute to loadings of other leading pollutants.

Table E-2 presents additional summary statistics from the 1998 *National Water Quality Inventory*. These figures indicate that agriculture contributes to the impairment of at least 170,000 river miles, 2.4 million lake acres, and almost 2,000 estuarine square miles. The portion of impairment attributable to animal agriculture nationwide is unknown, since not all states and

Table E-2. Summary of Statistics from the National U.S. Water Quality Impairment Survey, 1998

Total Quantity in U.S.	Waters Assessed	Quantity Impaired by All Sources	Quantity Impaired by Agriculture [a/]
Rivers 3,662,255 miles	23% of total (840,402 miles)	35% of assessed (291,263 miles)	59% of impaired (170,750 miles)
Lakes, Ponds, and Reservoirs 41.6 million acres	42% of total (17.4 million acres)	45% of assessed (7.9 million acres)	31% of impaired (2,417,801 acres)
Estuaries 90,465 square miles	32% of total (28,687 sq. miles)	44% of assessed (12,482 square miles)	15% of impaired (1,827 square miles)

Source: USEPA, 2000h.
[a/]AFOs are a subset of the agriculture category. Summaries of impairment by non-agricultural sources are not presented here.

tribes identified sources at the more specific levels. However, 28 state and tribes did identify specific agricultural activities contributing to water quality impacts on rivers and streams, and 16 states and tribes identified specific agricultural activities contributing to water quality impacts on lakes, ponds, and reservoirs. (In the 1996 Inventory, the following states reported impairment due to intensive animal operations: Hawaii, Illinois, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Montana, Nebraska, Ohio, Oklahoma, Rhode Island, South Carolina, Tennessee, Virginia, West Virginia, Wisconsin, and Wyoming. Other states reporting agricultural sources of impairment include: Arizona, Nevada, New Hampshire, New Mexico, and North Dakota.)

For rivers and streams, estimates from 38 states indicate that 16 percent of the total reported agricultural impairment is from animal feeding operations (including feedlots, animal holding areas, and other animal operations), and 17 percent of the agricultural impairment is from both range and pasture grazing. For lakes, ponds, and reservoirs, estimates from 16 states indicate that 4 percent of the total reported agricultural impairment is from animal feeding operations (including feedlots, animal holding areas, and other animal operations), and 39 percent of the agricultural impairment is from both range and pasture grazing. Impairment specifically due to land application of manure was not reported.

E.1.2 Pollutant Concentrations in Animal Manure and Wastewater

Table E-3 lists the reported amounts of macro- and micro-nutrients in livestock and poultry waste, along with documented levels of other inorganic and metallic constituents. As shown, the American Society of Agricultural Engineers (ASAE) reports that the constituents present in livestock and poultry manure include: boron (B), cadmium (Cd), calcium (Ca), chlorine

Table E-3. Nutrients, Metals, and Pathogens in Livestock and Poultry Manures

Constituent	Sector						
	Beef	Dairy	Veal	Hog	Broiler	Layer	Turkey
	(average pounds per 1,000 pounds live animal weight per day)						
Mass of animal	793.7	1410.9	200.6	134.5	992.1	4.0	4.0
Manure (wet basis)	58	86	62	84	85	64	47
Urine	18	26		39			
Density (lbs/ft^3)	1000	990	1000	990	1000	970	1000
Total Solids	8.5	12.0	5.2	11.0	22.0	16.0	12.0
Volatile Solids	7.2	10.0	2.3	8.5	17.0	12.0	9.1
BOD (5-day)	1.6	1.6	1.7	3.1		3.3	2.1
COD (5-day)	7.8	11.0	5.3	8.4	16.0	11.0	9.3
pH	7.0	7.0	8.1	7.5		6.9	
Nitrogen (Total Kjeldahl)	3.40e-01	4.50e-01	2.70e-01	5.20e-01	1.10e+00	8.40e-01	6.20e-01
Nitrogen (Ammonia)	8.60e-02	7.90e-02	1.20e-01	2.90e-01		2.10e-01	8.00e-02
Phosphorus (Total)	9.2e-02	9.4e-02	6.6e-02	1.8e-01	3.0e-01	3.0e-01	2.3e-01
Orthophosphorus	3.0e-02	6.1e-02		1.2e-01		9.0e-02	
Potassium	2.1e-01	2.9e-01	2.8e-01	2.9e-01	4.0e-01	3.0e-01	2.4e-01
Calcium	1.4e-01	1.6e-01	5.9e-02	3.3e-01	4.1e-01	1.3e+00	6.3e-01
Magnesium	4.9e-02	7.1e-02	3.3e-02	7.0e-02	1.5e-01	1.4e-01	7.3e-02
Sulfur	4.5e-02	5.1e-02		7.6e-02	8.1e-02	1.4e-01	
Sodium	3.0e-02	5.2e-02	8.9e-02	6.7e-02	1.5e-01	1.0e-01	6.6e-02
Chloride		1.3e-01		2.6e-01		5.6e-01	
Iron	7.8e-03	1.2e-02	3.3e-04	1.6e-02		6.0e-02	7.5e-02
Manganese	1.2e-03	1.9e-03		1.9e-03		1.0e-03	2.4e-03
Boron	8.8e-04	7.1e-04		3.1e-03		1.8e-03	
Molybdenum	4.2e-05	7.4e-05		2.8e-05		3.0e-04	
Zinc	1.1e-03	1.8e-03	1.3e-02	5.0e-03	3.6e-03	1.9e-02	1.5e-02
Copper	3.1e-04	4.5e-04	4.8e-05	1.2e-03	9.8e-04	8.3e-04	7.1e-04
Cadmium		3.0e-06		2.7e-05		3.8e-05	
Nickel		2.8e-04				2.5e-04	

Table E-3. Nutrients, Metals, and Pathogens in Livestock and Poultry Manures (continued)

Constituent	Sector						
	Beef	Dairy	Veal	Hog	Broiler	Layer	Turkey
	(average pounds per 1,000 pounds live animal weight per day)						
Lead				8.4e-05		7.4e-04	
Arsenic	na	na	na	6.9e-04	4.8e-04	5.5e-06	na
Total coliform bacteria	29	500		21		50	
Fecal coliform bacteria	13	7.2		8		3.4	0.62
Fecal streptococcus bacteria	14	42		240		7.4	

Source: ASAE, 1993. Arsenic values are from NCSU, 1994. Converted from reported (lb./yr./1,000 lb. animal weight) values of 0.002 (layers), 0.176 (broilers), and 0.252 (hogs). All values are in pounds unless otherwise noted.

(Cl), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), potassium (K), sodium (Na), sulfur (S), zinc (Zn), nitrogen (N) and phosphorus (P) species, total suspended solids (TSS), and pathogens (ASAE, 1993). Other research conducted by various land grant universities reports that arsenic, selenium, and other constituents are also present in some animal manures (NCSU, 1994; Sims, 1995).

Concentrations shown in Table E-3 are reported in pounds per 1,000 pounds of live animal weight per day and vary by animal species. As shown in Table E-3, poultry manure generally has a higher nutrient content than most other farm animal manure and wastewater. Actual nutrient values of manure depend on many factors, including: animal size, maturity, and species; health and diet of the animals; and the feed composition and the protein content of the ration fed (USDA, 1992). Additional details on the constituents in animal manure are provided in the *Environmental Assessment* (USEPA, 2000b) and the *Development Document* (USEPA, 2000a).

E.2 ESTIMATED POLLUTANT REMOVALS

For this analysis, EPA estimates the expected reduction of selected pollutants for each of the regulatory options considered. These estimates measure the amount of nutrients, sediments, and metals originating from animal production areas that are removed under a post-regulation scenario (as compared to a baseline scenario) and do not reach U.S. waters. Additional information on EPA's estimated loadings and removals under post-compliance conditions is provided in the *Development Document* (USEPA, 2000a) and the *Benefits Analysis* (USEPA, 2000d) that support the rulemaking.

USDA estimates that manure nutrients available for land application from all confined livestock and poultry operations totaled 2.6 billion pounds of nitrogen and 1.4 billion pounds of phosphorus in 1997 (Kellogg, et al., 2000).[4] EPA equates these estimates to the total amount of manure and nutrients generated at animal feeding operations. Of this amount generated, EPA estimates that between 64 percent (two-tier) and 72 percent (three-tier) of all CAFO manure would be covered by the proposed regulation. More information on these estimates are presented in Section 2 of this report. Table E-4 shows these estimates broken out by major subcategory.

Table E-4. Nutrients Generated from CAFOs and Loadings that Discharge to U.S. Waters (Baseline)

Sector	"Available for Land Application" (>500AU) [a/]		"Edge-of-Field" (>500AU) [b/]	
	Nitrogen	Phosphorus	Nitrogen	Phosphorus
	(million pounds)			
Cattle	450.9	313.8	122.7	55.9
Dairy	254.3	97.6	56.9	138.7
Hogs	187.5	189.4	68.8	129.9
All Poultry	967.6	464.8	186.2	405.6
Sum Total	**1,860.3**	**1,065.5**	**434.6**	**730.0**

NA=Not Available.
Source(s):
"Edge-of-field" loadings measure cropland runoff from land application of manure and wastewater. Estimates of the amount discharged to U.S. waters are derived based on percentage difference in estimated "At-Stream" loadings. Baseline reflects pre-regulatory loadings.
[a/]Manure nutrients generated at animal feeding operations with more than 500 AU are derived by EPA from estimated loadings from USDA/NRCS staff (Kellogg, et al., 2000 forthcoming) using 1997 Census of Agriculture (USDA/NASS, 1999a) and procedures documented in Kellogg et al. (2000) and Lander et al. (1998). Additional information is presented in Section 2 of this report.
[b/]USEPA, 2000a. "Edge-of-field" loadings measure cropland runoff from land applied manure and wastewater.

Table E-4 also shows EPA's aggregated estimates of loadings that reach the "edge-of-field" from land applied manure by AFOs with more than 500 AU. EPA estimates these loadings using a simulation modeling approach based on representative model CAFOs (similar to that used to estimate compliance costs of the proposed regulations, as described in Section 4). This model uses estimates of manure generation and information on cropping systems specific to animal operations under various pre- and post-regulation model simulation conditions. Model CAFOs take into account differing conditions at CAFOs. These conditions include animal type, production region, facility size, current management systems and practices, and regionally based

[4]USDA's estimates do not include manure generated from other animal agricultural operations, such as sheep and lamb, goats, horses, and other miscellaneous animal species.

physiographic conditions regarding soil, rainfall, hydrology, crop rotation, and other factors. More details on these models and a summary of the estimated loadings and post-compliance reductions are provided in the *Development Document* (USEPA, 2000a).

EPA evaluates post-regulatory conditions in terms of expected reductions from estimated baseline (pre-regulatory) loadings. (Baseline loadings are shown in Table E-4 and E-5, and estimated post-compliance reductions are discussed later in Sections E-3 and E-4.) EPA's model simulates loadings and reductions for total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS). Under this approach, EPA also simulates loadings and reductions for six selected metallic compounds that are present in animal manure (Cd, Cu, Ni, Pb, Zn, As) and also pathogens (expressed as fecal coliform and fecal streptococcus). Estimated baseline metallic compound loadings from CAFOs are shown in Table E-5. Additional information on this approach is provided in the *Development Document* (USEPA, 2000a).

Table E-5. Estimated Metals Generated and "Edge-of-Field" Loadings from CAFOs

Sector	"Edge-of-Field" Baseline Loadings					
	Cadmium	Copper	Lead	Nickel	Zinc	Arsenic
	(million pounds)					
Cattle	0.06	1.65	1.54	0.38	34.90	0.20
Dairy	0.00	0.57	0.11	0.35	2.26	0.00
Hogs	0.01	0.07	0.04	0.13	2.70	0.33
All Poultry	0.10	3.07	2.85	0.80	66.06	0.40
Sum Total	0.17	5.36	4.54	1.66	105.91	0.75

Source: USEPA, 2000a. "Edge-of-field" loadings measure cropland runoff from land application of manure and wastewater. Estimates of the amount discharged to U.S. waters are derived based on percentage difference in estimated "At-Stream" loadings.

EPA uses the estimated "edge-of-field" loadings shown in Table E-4 as inputs to its water quality modeling framework that determines the pollutant loadings reaching U.S. waterways. Information on EPA's fate and transport model and a comparison of "edge-of-field" loadings and pollutants that reach U.S. waters (measured as rivers and streams), referred to here as "at-stream" loadings, is provided in the *Benefits Analysis* (USEPA, 2000d). This analysis indicates that about 70 percent of all land applied manure phosphorous and sediments in applied manure reach U.S. waters; about 90 percent of all land applied manure nitrogen is estimated to reach U.S. waters (USEPA, 2000d). This level of nutrients reaching U.S. waters is explained by differing assumptions on a variety of levels, including manure generation by animal species, the share of animals in confinement, and losses due to volatization and management practice, as well as other factors, including rounding and truncation error and assumptions regarding background levels. More information is available in the *Development Document* (USEPA, 2000a) and the *Benefits Analysis* (USEPA, 2000d).

E.3 COST-EFFECTIVENESS ANALYSIS: TOXIC POLLUTANTS

This section reviews EPA's C-E analysis for selected toxic pollutant removals found in animal manure. This analysis follows the guidelines of a standard C-E analysis commonly used by EPA to compare the efficiency of regulatory options for effluent guidelines in removing priority and non-conventional pollutants.

This analysis evaluates cost-effectiveness as the incremental and average annualized cost of a pollution control option in an industry (or industry subcategory) per incremental and total pound equivalent of pollutant (i.e., pound of pollutant adjusted for toxicity) removed by that control option. Section E.3.1 outlines this approach. The C-E analysis primarily enables EPA to compare the removal efficiencies of regulatory options under consideration for a rule. Section E.3.2 presents these results. A secondary use is to compare the cost-effectiveness of the proposed option for the effluent guidelines to that of effluent guidelines for other industries, as shown in Section E.3.3.

E.3.1 Methodology

Performing a standard EPA C-E analysis involves the following seven steps:

1. Determine the pollutants of concern (priority or other pollutants).
2. Estimate relative toxic weights for these pollutants.
3. Define the regulatory pollution control options.
4. Calculate pollutant removals for each control option.
5. Determine the total annualized cost for each control option.
6. Calculate cost-effectiveness values (and adjust to 1981 dollars).
7. Compare cost-effectiveness values.

For this C-E analysis, EPA has identified six toxic pollutants of concern (step 1), including arsenic, zinc, copper cadmium, nickel, and lead. Factors considered in selecting these pollutants included toxicity, frequency of occurrence in wastestream effluent, and amount of pollutant in the waste stream (USEPA, 2000a). As shown in Table E-3, this is a subset of all the toxic compounds reported to be present in farm animal manures (which varies by animal type). Therefore, the cost-effectiveness results presented here are conservative (i.e., a higher per-pound removal value is estimated than would be the case if all metals were considered in this analysis).

Table E-6 presents the toxic weighting factors (TWFs) for the regulated pollutants used in this C-E analysis (step 2). In C-E analyses, EPA measures pollutant removals in toxicity normalized units called "pounds-equivalent," where the pounds-equivalent removed for a particular pollutant is determined by multiplying the number of pounds of a pollutant removed by each option by a TWF for each pollutant. EPA uses these factors to account for differences in toxicity among the pollutants and to adjust the estimated pollutant loading values to account for

Table E-6. Total Metal Removals "At Stream" by Regulatory Option Considered

Metal	TWF	Proposed BAT Option		Option 1		Option 3+5	
		Lbs.	Lbs.-Eq.	Lbs.	Lbs.-Eq.	Lbs.	Lbs.-Eq.
		(millions of pounds or pounds-equivalent)					
Zinc	0.047	59.0	2.8	51.2	2.4	59.0	2.8
Copper	0.63	2.9	1.8	2.4	1.5	2.9	1.8
Cadmium	2.6	0.1	0.3	0.1	0.3	0.1	0.3
Nickel	0.11	2.4	0.3	2.1	0.2	2.4	0.3
Lead	2.2	0.9	1.9	0.7	1.5	0.9	1.9
Arsenic	4	0.4	1.4	0.2	1.0	0.4	1.4
Total	NA	65.7	8.4	56.7	6.8	65.7	8.4

Source: Toxic weighting factors (TWF) are calculated by EPA and are based on freshwater chronic criteria for copper (USEPA, 2000j). Pound removals are estimated by EPA (USEPA, 2000a). Pounds-equivalent are calculated by multiplying the estimated pounds of removals by the TWFs shown here.

the fact that different pollutants have different potential effects on human and aquatic life (e.g., a pound of zinc in an effluent stream has a different effect than a pound of arsenic).

EPA derives TWFs for pollutants using ambient water quality criteria and toxicity values.[5] The factors are standardized by relating them to a "benchmark" toxicity value that was based on the toxicity of copper when the methodology was developed.[6] For most pollutants, EPA uses established chronic freshwater aquatic criteria to derive toxic weighting factors. In cases where a human health criterion has also been established for the consumption of fish, the sum of both the human and aquatic criteria are used. The toxic weighting factor is the sum of two criteria-weighted ratios: the "benchmark/old" copper criterion divided by the human health criterion for the particular pollutant and the "benchmark/old" copper criterion divided by the aquatic chronic criterion. This is shown in the following equation:

$$TWF_j = \frac{5.6}{HHC_j} + \frac{5.6}{AqHC_j}$$

where:

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[5]Human health and aquatic chronic criteria are maximum contamination thresholds. Units for criteria are micrograms of pollutant per liter of water. Most values are those reported in the toxicology literature.

[6]Although the water quality criterion has been revised (to 12.0 µg/l), all cost-effectiveness analyses for effluent guideline regulations continue to use the "old" criterion of 5.6 µg/l as a benchmark so that cost-effectiveness values can continue to be compared to those for other effluent guidelines. Where copper is present in the effluent, the revised higher criterion for copper results in a toxic weighting factor for copper of 0.467 rather than 1.0.

HHC_j	=	Human Health Criteria for pollutant j (if available)
$AqHC_j$	=	Aquatic Health Criteria for pollutant j
Constant (5.6)	=	"Benchmark/old" criterion for copper

Given the established values for these criteria, the TWF for each pollutant can be calculated (USEPA, 2000f). For example, for cadmium, the human health criteria is 84 and the aquatic health criteria is 1.1. This translates to a TWF for cadmium of 5.16 (Table E-6). EPA uses TWFs for the selected priority pollutants (Cd, Cu, Ni, Pb, Zn, As) to adjust estimated removals to a "pounds-equivalent" basis (as shown in Table E-6) by multiplying the estimated pounds of removals by the TWFs.

This C-E analysis investigates three pollution control options (step 3). As discussed in Section 3 of this report, the proposed BAT Option being proposed for this rulemaking is a combination of Option 3 for beef and dairy (except veal) and Option 5 for pork, veal, and poultry. In addition, the analysis presents results for the two co-proposed regulatory scenarios (Scenario 4a, the two-tier structure, and Scenario 3, the three-tier structure). Results for Scenario 5 (two-tier structure at 750 AU threshold) and Scenario 6 are not determined, but fall within the range of results shown over all scenarios discussed. The two-tier structure includes all operations with more than 500 AU, while the three-tier structure may include operations with more than 300 AU that meet the "risk-based" conditions (see Section 3). Two alternative regulatory options considered for comparison in this cost-effectiveness analysis are Option 1 and a "worst-case" option that combines the full cost of Option 3 and with the full cost of Option 5 for all subcategories.[7] This latter option is called Option 3+5. These alternative options were chosen for comparison because they generally represent the lower and upper bound of costs and removals: Option 1 represents the lowest costs and least removals and Option 3+5 represents the highest costs and removals.[8] In addition, two alternative NPDES Scenarios are shown: CAFOs with more than 1,000 AU and with more than 300 AU. The differences in CAFO coverage provide an upper and lower bound of the analysis to roughly depict the alternative NPDES scenarios, including Scenario 4b (operations >300 AU) and Scenario 1 (approximated using estimates for operations >1,000 AU). These options/scenarios are described in detail in Section 3 of this report.

First, EPA calculates pollutant loadings for each animal sector under each regulatory option (step 4). EPA then calculates pollutant removals as the difference between baseline and post-treatment discharges. Tables E-4 and E-5 present the baseline (pre-regulatory) loadings and

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[7]Calculated for this analysis as the reported cost of Option 3 (Tables 5-1 and 5-2) plus the cost of Option 5, minus the cost of Option 2 (see Tables 5-1 and 5-2), since both Option 3 and 5 are incremental to Option 2.

[8]See Section 10 for pre-tax annualized costs and the *Development Document* (USEPA, 2000a) for estimated removals.

removals for the proposed BAT option, as described in Section E.2.[9] The estimated removals are weighted using the toxic weighting factors (Table E-6) and are reported in pounds-equivalent (lb.-eq.) across all pollutants. Finally, EPA calculates total weighted removals for each regulatory option by summing the removals for each of the identified priority pollutants for each option (see Table E-7). For more information, see the *Development Document* (USEPA, 2000a).

Pre-tax annualized costs of compliance for each regulatory option (step 5) have been developed by EPA and are presented in Section 10 of this report. Estimated costs include private sector costs of purchasing, installing, and operating pollution control systems,[10] as well as administrative costs to state and federal governments for authorizing NPDES permits (Section 10) and costs to offsite recipients of CAFO manure (Section 5 and, also, USEPA, 2000a). Table E-7 presents the aggregate annual pre-tax costs by option. For the purpose of comparing C-E values of options under review to those of other promulgated rules, estimated compliance costs (which are reported in 1999 dollars in Section 10, but are originally developed in 1997 dollars) are adjusted to 1981 dollars using *Engineering News Record*'s Construction Cost Index (CCI) (ENR, 2000). Table E-7 shows compliance costs for the proposed CAFO regulations in 1981 dollars. For this analysis, this adjustment factor is calculated as follows:

Adjustment factor = (1981 CCI)/(1997 CCI) = 3,535/5,825 = 0.6069

EPA calculates cost-effectiveness values separately for each regulatory option (step 6) and reports these in units of dollars per pound-equivalent of pollutant removed. Generally, options first are ranked in ascending order of pounds-equivalent of pollutants removed. The incremental cost-effectiveness value for a particular control option is calculated as the ratio of the incremental annual cost to the incremental pounds-equivalent removed. The average cost-effectiveness value for each option is calculated as total dollars for the option divided by total pounds-equivalent removed by the option. The incremental cost-effectiveness values are viewed in comparison to the baseline (zero costs/zero removals) for the first option and to the preceding regulatory option. Cost-effectiveness values are reported in units of dollars per pound-equivalent of pollutant removed. In this report, EPA presents average cost-effectiveness values, as discussed below.

Cost-effectiveness values can be compared across regulatory alternatives according to either the average or the incremental cost-effectiveness (step 7). Average cost-effectiveness values for each option are calculated as total dollars for the option divided by total pounds-equivalent removed by the option. Average cost-effectiveness reflects the "increment" between no regulation and the regulatory options shown. Incremental cost-effectiveness is the appropriate

[9]Pollutant loadings and removals for Options 1 and 3+5 are included in the *Development Document* (USEPA, 2000a) and the *Environmental Assessment* (USEPA, 2000b).

[10]Every dollar spent on compliance can be applied against a firm's taxable income. Due to various tax mechanisms such as accelerated depreciation, this reduction means that firms face only about 70 percent of compliance costs after taxes.

measure for comparing one regulatory option to an alternative, less stringent regulatory option for the same subcategory. The incremental cost-effectiveness value for a particular control option is calculated as the ratio of the incremental annual cost (e.g., the difference in cost between the option removing the least pollutants to the next better option) to the incremental pounds-equivalent removed (calculated between the same options). The equation EPA uses to calculate incremental cost-effectiveness is:

$$CE_k = \frac{ATC_k - ATC_{k-1}}{PE_k - PE_{k-1}}$$

where:

CE_k = Cost-effectiveness of Option k
ATC_k = Total annualized treatment cost under Option k
PE_k = Pounds-equivalent removed by Option k

The numerator of the equation, ATC_k minus ATC_{k-1}, is the incremental annualized treatment cost in going from Option k-1 (an option that removes fewer pounds-equivalent of pollutants) to Option k (an option that removes more pounds-equivalent of pollutants). The denominator is similarly the incremental removals achieved in going from Option k-1 to k. Thus, cost-effectiveness measures the incremental unit cost of pollutant removal of Option k (in pound equivalents) in comparison to Option k-1. Average cost-effectiveness values can also be derived using this equation by setting ATC_{k-1} to zero and by setting the pollutant loadings (PE_{k-1}) to the baseline loadings.

Because the options are ranked in ascending order of pounds-equivalent of pollutants removed, any option that has higher costs but lower removals than another option immediately can be identified (the cost-effectiveness value for the next option becomes negative). When negative values are computed for Option k, Option k-1 will be noted as "dominated" (having a higher cost and lower removals than Option k). Option k-1 is then removed from the cost-effectiveness calculations, and all cost-effectiveness values within a regulatory grouping are then recalculated without the "dominated" option. This process continues until all "dominated" options are eliminated. The remaining options can then be presented in terms of their incremental cost-effectiveness values and are considered viable options for regulatory consideration.

These values can be used, with caution, to compare an option to previously promulgated effluent limitations guidelines. Because Option 3+5 (all subcategories) removes no more pollutants at a higher cost than the proposed BAT Option, Option 4 is dominated. Because Option 4 is dominated, incremental cost-effectiveness is not meaningful. Thus EPA presents, in Section E.3.2, the average cost-effectiveness results for the proposed BAT Option, Option 1, and Option 3+5 at each size cutoff.

EPA generally ranks options in order of increasing pounds-equivalent removed to identify the point at which increased removal of pollutants is no longer cost-effective. EPA typically determines this point be where costs (per pound-equivalent removed) increase sharply, that is, where relatively few incremental pounds are removed for steady increases in cost. The accompanying figure (Figure E-1) shows this point as Point A, where the cost-effectiveness curve

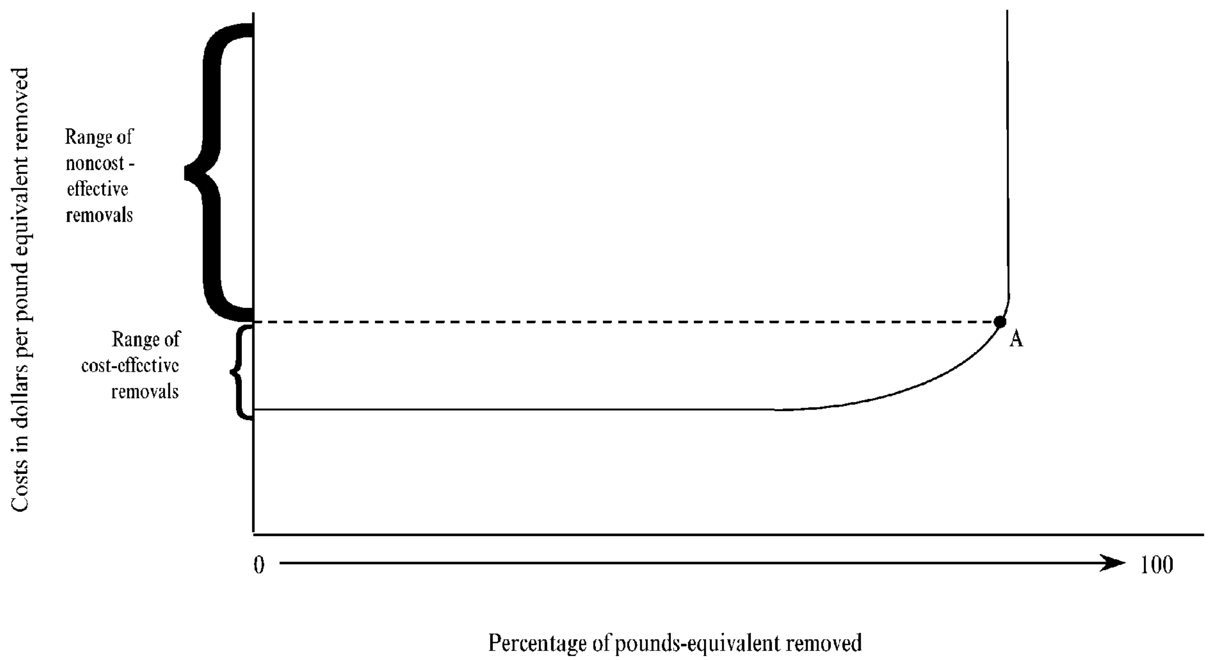

Figure E-1. Cost-Effectiveness

becomes nearly vertical. Increases in removals beyond this point come only at relatively high unit costs, which in many cases EPA will determine exceed the benefit of the increased removals to society.

E.3.2 Cost-Effectiveness Results

Table E-7 presents cost-effectiveness results for the proposed BAT Option under both co-proposed scenarios, Scenario 4a (two-tier structure) and Scenario 3 (three-tier structure) with regard to priority pollutants. Also shown are the results for alternative regulatory options that were considered by EPA. Results shown in Table E-7 for select technology options, including the proposed BAT Option (Option 3 for beef and dairy subcategories, except veal, and Option 5 for

Table E-7. Cost-Effectiveness Results by Select Regulatory Option/Scenario ($1981)

Option	Total Annual		Average Cost-Effectiveness	Incremental Cost-Effectiveness
	Pounds-equivalent Removed [a/]	Total Cost [b/]		
	(million pounds)	($ millions)	($/lbs.-eq.)	
ELG Option 3 (Beef/Dairy) and 5 (Swine/Veal/Poultry)				
>1000 AU	5.3	$402	$76	$76
>500 AU "Two-Tier"	8.4	$491	$58	$29
>300 AU "Three-tier"	9.4	$518	$55	$27
>300 AU (Scenario 4b)	9.4	$579	$62	undefined
ELG Option 1 (All Subcategories)				
>1000 AU	4.2	$211	$50	$50
>500 AU "Two-Tier"	6.8	$258	$38	$18
>300 AU "Three-tier"	7.5	$277	$37	$27
>300 AU (Scenario 4b)	7.5	$297	$40	undefined
ELG Option 3+5 (All Subcategories)				
>1000 AU	5.3	$1,047	$197	$197
>500 AU "Two-Tier"	8.4	$1,212	$144	$53
>300 AU "Three-tier"	9.4	$1,254	$134	$43
>300 AU (Scenario 4b)	9.4	$1,354	$144	undefined

Options/Scenarios are described in Table 3-1.
[a/] Pounds-equivalent removals are calculated from removals estimated by EPA's loadings analysis, described in the *Benefits Analysis* (USEPA, 2000d) and the *Development Document* (USEPA, 2000a), adjusting for each pollutant's toxic weight (as described Section E.3.1).
[b/] Costs are pre-tax and indexed to 1981 dollars using the Construction Cost Index (ENR, 2000).

the swine, veal, and poultry subcategories) and Option 3+5 (both Option 3 and 5 for all subcategories). Options are shown for four CAFO coverage scenarios, including CAFOs with more than 1,000 AU and CAFOs with more than 500 AU (two-tier structure), and operations with more than 300 AU, both under Scenario 4b and as defined under Scenario 3 (three-tier structure). The differences in CAFO coverage provide an upper and lower bound of the analysis to roughly depict the alternative NPDES scenarios. Both incremental and average C-E values are shown.

Incremental cost-effectiveness is the appropriate measure for comparing one regulatory alternative to another for the same subcategory. In general, the lower the incremental C-E value, the more cost-efficient the regulatory option is in removing pollutants, taking into account their toxicity. For this rulemaking, EPA compares the cost-effectiveness across alternative NPDES Scenarios to assess the Agency's decision to define as CAFO operations with more than 500 AU (two-tier structure) and, alternatively, operations with more than 300 AU, as defined by Scenario 3 (three-tier structure).

As shown in Table E-7, the BAT Option is the most cost-efficient under each of the co-proposed alternatives. Under both the two-tier (500 AU) and three-tier structures, EPA estimates an incremental cost-effectiveness value of about $30 per pounds-equivalent (lbs.-eq.) removed. In comparison, an alternative scenario covering operations with more than 1,000 AU has a higher estimated incremental cost-effectiveness ($76/lbs.-eq., as shown in Table E-7). (Since the change in removals between Scenario 3 and Scenario 4b is zero, the incremental C-E value is "undefined.") The BAT Option is also more efficient than requiring Option 3+5 for all subcategories, which has higher costs but results in no additional pollutant removals compared to the BAT Option. This is because the ELG options differ mostly in terms of their monitoring and sampling requirements but establish no additional pollutant controls. (Since the change in removals between the BAT Option and Option 3+5 is zero, the incremental C-E value is undefined.)

The average cost-effectiveness reflects the "increment" between no regulation and regulatory options shown. For the BAT Option, EPA estimates an average value at $55 per lbs.-eq. to $58 per lbs.-eq., depending on the proposed tier structure (Table E-7). These estimated average values are low compared to the alternative NPDES scenarios since the average cost-effectiveness value is higher ($76/lbs.-eq., if all CAFOs with more than 1,000 AU are regulated; $62/lbs.-eq. for all CAFOs with more than 300 AU). This average cost is also low compared to previous ELG rulemakings, where estimated costs have, in some cases, exceeded $100/lbs.-eq. removed. This information is provided in Section E.3.3. In addition, as shown in Table E-7, average cost-effectiveness is more than twice as high under the more stringent Option 3+5 for all subcategories (estimated at more than $100 per lbs.-eq. removed). Costs, but also removals, are lower under the less stringent Option 1 (also referred to as the "nitrogen-based" option) compared to other technology options. The average cost-effectiveness of Option 1 is $38/lbs.-eq. under the two-tier structure and $37/lb.-eq. under the three-tier structure. As described in Section VIII of the preamble, EPA determined that this option would not represent the best available technology and so chose not to propose it.

Tables E-8 and E-9 show the results of EPA's analysis of average cost-effectiveness by major subcategory groupings (cattle, dairy, hogs, and poultry) for the BAT Option under the two-tier and three-tier structures, respectively. As shown in Tables E-8 and E-9, under both co-proposed scenarios, there is a wide discrepancy in cost-effectiveness among the commodity sectors. In particular, the cost to remove a pound of toxic pound-equivalent is greatest in the hog and dairy sectors. The average cost-effectiveness of the proposed BAT Option is more than $100 per pound-equivalent in these two sectors under either co-proposed scenario, whereas removal costs are about $55/lbs.-eq. for cattle (includes beef, veal, and heifer) and about $17/lbs.-eq. for poultry under either tier (Tables E-8 and E-9).

Table E-8. Cost-Effectiveness Results by Sector under the Two-Tier Structure (Scenario 4a)($1981)

Sector	Total Annual		Average Cost-Effectiveness
	Pounds-equivalent Removed [a/]	**Total Cost [b/]**	
	(million pounds)	($ millions)	($/lbs.-eq.)
ELG Option 3 (Beef/Dairy) and 5 (Swine/Veal/Poultry)			
Cattle	2.4	$135.2	$55.2
Dairy	0.7	$104.8	$150.8
Hogs	0.7	$171.9	$260.9
Poultry	4.6	$79.0	$17.1
ELG Option 1 (All Subcategories)			
Cattle	2.3	$50.0	$21.5
Dairy	0.6	$61.1	$109.0
Hogs	0.2	$80.7	$403.1
Poultry	3.7	$66.2	$17.8
ELG Option 3+5 (All Subcategories)			
Cattle	2.4	$670.7	$273.9
Dairy	0.7	$206.7	$297.3
Hogs	0.7	$288.4	$437.7
Poultry	4.6	$161.6	$35.0

Options/Scenarios are described in Table 3-1. "Cattle" include beef, heifer, and veal operations. "Poultry" includes broiler, egg, and turkey operations.

[a/]Pounds-equivalent removals are calculated from removals estimated by EPA's loadings analysis, described in the *Benefits Analysis* (USEPA, 2000d) and the *Development Document* (USEPA, 2000a), adjusting for each pollutant's toxic weight (as described Section E.3.1).

[b/]Costs are pre-tax and indexed to 1981 dollars using the Construction Cost Index (ENR, 2000).

Table E-9. Cost-Effectiveness Results by Sector under the Three-Tier Structure (Scenario 3)($1981)

Sector	Total Annual		Average Cost-Effectiveness
	Pounds-equivalent Removed [a/]	Total Cost [b/]	
	(million pounds)	($ millions)	($/lb.-eq.)
ELG Option 3 (Beef/Dairy) and 5 (Swine/Veal/Poultry)			
Cattle	2.5	$136.7	$55.7
Dairy	1.0	$128.0	$132.3
Hogs	0.8	$160.3	$212.4
Poultry	5.2	$92.5	$17.7
ELG Option 1 (All Subcategories)			
Cattle	2.3	$51.1	$21.9
Dairy	0.8	$70.3	$90.9
Hogs	0.2	$78.5	$355.2
Poultry	4.2	$77.2	$18.4
ELG Option 3+5 (All Subcategories)			
Cattle	2.5	$671.8	$273.7
Dairy	1.0	$250.4	$258.8
Hogs	0.8	$270.4	$358.3
Poultry	5.2	$190.7	$36.6

Options/Scenarios are described in Table 3-1. "Cattle" include beef, heifer, and veal operations. "Poultry" includes broiler, egg, and turkey operations.

[a/] Pound-equivalent removals are calculated from removals estimated by EPA's loadings analysis, described in the *Benefits Analysis* (USEPA, 2000d) and the *Development Document* (USEPA, 2000a), adjusting for each pollutant's toxic weight (as described Section E.3.1).

[b/] Costs are pre-tax and indexed to 1981 dollars using the Construction Cost Index (ENR, 2000).

E.3.3 Comparison of Cost-Effectiveness Values with Promulgated Rules

Incremental cost-effectiveness is the appropriate measure for comparing one regulatory option to an alternative, less stringent regulatory option for the same rule. For comparing the overall cost-effectiveness of one rule to another, average cost-effectiveness may be a more appropriate measure, but must be considered in context with caution. (Average cost-effectiveness can be thought of as the "increment" between no regulation and the selected option for any given rule.)

Table E-10 presents the incremental cost-effectiveness values for the proposed regulatory option under the two co-proposed regulatory scenarios and the values for effluent guidelines issued for other industries. The numbers presented here for this rulemaking are pre-tax costs.[11] As Table E-10 shows, the incremental cost-effectiveness of the proposed BAT Option is $29 or $27 per pound-equivalent removed, for the two-tier and three-tier structures, respectively (also see Table E-7). Compared with other effluent guidelines, EPA considers this rule to be cost-effective under either co-proposed scenario.

Table E-10. Industry Comparison of BAT Cost-Effectiveness for Direct Dischargers [a/]

Industry	Pounds-Equivalent Currently Discharged	Pounds-Equivalent Remaining at Selected Option(s)	Cost-Effectiveness of Selected Option(s) ($/PE removed)
	(1,000's)		($/lb-equiv. removed)
Aluminum Forming	1,340	90	121
Battery Manufacturing	4,126	5	2
CAFOs (two-tier)	12,273	3,857	29
CAFOs (three-tier)	13,700	4,305	27
Canmaking	12	0	10
Centralized Waste Treatment [b/]	3,372	1,261 - 1,267	5 - 7
Coal Mining	BAT=BPT	BAT=BPT	BAT=BPT
Coil Coating	2,289	9	49
Copper Forming	70	8	27
Electronics I	9	3	404
Electronics II	NA	NA	NA
Foundries	2,308	39	84
Inorganic Chemicals I	32,503	1,290	<1
Inorganic Chemicals II	605	27	6
Iron and Steel	40,746	1,040	2
Leather Tanning	259	112	BAT=BPT
Metal Finishing	3,305	3,268	12
Metal Products and Machinery[b]	140	70	50
Nonferrous Metals Forming	34	2	69

[11]Average C-E values presented for other effluent guidelines (Table E-10) may be expressed in terms of after-tax costs—that is, the costs actually faced by the firms, not the total cost of the regulation to industry (which is subsidized by reductions in taxable income). Because of these factors, direct comparisons between this rulemaking and others cannot be made easily. The equivalent after-tax cost is approximately 60-70 percent of pre-tax costs.

Table E-10. Industry Comparison of BAT Cost-Effectiveness for Direct Dischargers (continued) [a/]

Industry		Pounds-Equivalent Currently Discharged	Pounds-Equivalent Remaining at Selected Option(s)	Cost-Effectiveness of Selected Option(s) ($/PE removed)
		(1,000's)		($/lb-equiv. removed)
Nonferrous Metals Manufacturing I		6,653	313	4
Nonferrous Metals Manufacturing II		1,004	12	6
Oil and Gas: Offshore Coastal Produced Water/TWC Drilling Waste		3,809 951 BAT=Current Practice	2,328 239 BAT=Current Practice	33 35 BAT=Current Practice
Organic Chemicals[b]		54,225	9,735	5
Pesticides		2,461	371	14
Pharmaceuticals[b]	A/C	560	550	224
	B/D	0.1	—	BAT=BPT
Plastics Molding and Forming		44.0	41	BAT=BPT
Porcelain Enameling		1,086	63	6
Petroleum Refining		BAT=BPT	BAT=BPT	BAT=BPT
Pulp and Paper		15,524	4,069	14
Textile Mills		BAT=BPT	BAT=BPT	BAT=BPT
Transportation Equipment Cleaning[c]		15	0.8	108

Toxic and Nonconventional Pollutants Only; Copper-Based Weights; $1981.
[a/]Although toxic weighting factors for priority pollutants varied across these rules, this table reflects the cost-effectiveness at the time of regulation.
[b]/Reflects costs and removals of both air and water pollutants.

E.4 COST-EFFECTIVENESS ANALYSIS: NUTRIENTS AND SEDIMENTS

In addition to conducting a standard C-E analysis for selected toxic pollutants (Section E.3), EPA also evaluates the cost-effectiveness of removing selected non-conventional and conventional pollutants, including nitrogen (N), phosphorus (P), and sediments. For this analysis, sediments are used as a proxy for TSS.

This analysis does not follow the methodological approach of a standard C-E analysis. Instead, this analysis compares the estimated compliance cost per pound of pollutant removed to a recognized benchmark, such as EPA's benchmark for conventional pollutants or other criteria for existing treatment, as reported in available cost-effectiveness studies. A review of this literature is provided in Section E.4.1. EPA uses these estimates to evaluate the efficiency of regulatory options in removing a range of pollutants and to compare the proposed BAT Option under the co-proposed scenarios to other regulatory alternatives (Section E.4.2). This approach also allows

EPA to assess the types of management practices that would be implemented to comply with the proposed regulations.

E.4.1 Review of Literature

EPA has reviewed the available information on pollutant removal costs for nutrients and sediments. This research can be broadly grouped according to estimates derived for industrial point sources (PS) and various nonpoint sources (NPS), including agricultural operations. In general, the PS research provides information on technology and retrofitting costs—and in some cases, cost per pound of pollutant removed—at municipal facilities, including publicly owned treatment works (POTWs) and wastewater treatment plants (WWTPs). This research differs from other cost-effectiveness estimates, since it utilizes actual cost data collected at a particular facility undergoing an upgrade. Other cost-effectiveness information is available based on the effectiveness of various nonpoint source controls and Best Management Practices (BMPs) and other pollutant control technologies that are commonly used to control runoff from agricultural lands. Typically, this information uses a modeling approach and simulates costs for a representative facility.

Table E-11 summarizes the cost-effectiveness values reported in the studies that were reviewed for this analysis. A wide range of costs per pound of pollutant removed is estimated by those studies where estimates span both point source and nonpoint sources, as well as those where estimates span a range of municipal, urban, and agricultural practices. Annualized costs also vary widely depending on a variety of factors, including the type of treatment system or practice evaluated, and whether the costs are evaluated as a retrofit to an existing operation or as construction of a new facility.

A series of case studies were compiled by researchers at Virginia Tech, who evaluated total costs for biological nutrient removal (BNR) retrofits at WWTPs throughout the Chesapeake Bay Watershed (Randall et al., 1999). These case studies were compiled to estimate a range of costs per pound of nitrogen removed at these facilities. This research was commissioned by EPA's Chesapeake Bay Program and was conducted with the assistance of the Maryland Department of the Environment and the Public Utilities Division of Anne Arundel County. As part of this work, BNR retrofit costs were estimated for 51 WWTPs located in Maryland, Pennsylvania, Virginia, and New York. The final report in this series compares these costs to the projected change in effluent total nitrogen concentrations, assuming that the influent flow meets the design or projected flow after 20 years (Randall, et al., 1999). As shown in Table E-11, this study concludes that the costs of nitrogen removal are very plant-specific and the costs per pound of addition nitrogen removal ranged from a projected savings of \$0.79 per pound to a cost of

Table E-11. Summary of Pollutant Removal Cost Estimates and Benchmarks

Type of Pollutant	Low Estimate	High Estimate	Treatment Type	Literature Sources
	($ per pound removed)			
Total Nitrogen (TN)	$0.79	$5.92	WWTPs	Randall et al (1999)
	--	$3.64	WWTPs	Wiedeman (2000)
	$0.91	$9.53	Ag. Lagoon	Tippett and Dodd (1995)
	$0.09	$2.18	Ag. Land Appl.	Tippett and Dodd (1995)
Total Phosphorus (TP)	$9.64	$165.00	Ag.(low) to municipal (high)	NEWWT 1994
	$270.34	$1,179.35	Large PS facility (0.2 mg/L)	LCBP (1995)
	$439.99	$544.32	Agricultural BMPs	LCBP (1995)
	$2.72	$135.17	Ag. Lagoon	Tippett and Dodd (1995)
	$0.36	$34.27	Ag. Land Appl.	Tippett and Dodd (1995)
Total Suspended Solids (TSS)	$0.01	$4.61	Ag.(low) to municipal (high)	NEWWT (1994)
	--	$0.25 [a]	POTWs (BOD and TSS)	USGPO (1986)
	$0.04	$0.18	Urban Stormwater Controls	USEPA (1999f)

WWTPs = Waste Water Treatment Plants; POTWs = Publicly owned treatment works.
[a/] TSS and BOD removals (1976 dollars). Indexed to $1999, estimated costs are $70 per pound removed.
Full citations are provided in references. Timeframe of dollar values shown vary by source (shown below).
Notes summarize timeframe of analysis, study assumptions (where available), and range of sources/treatment.
Randall et al. (1999): 1995-1998; 6% interest and 20-year capital renewal; BNR retrofits at WWTP only.
NEWWT (1994): 5% interest and 20-year capital renewal; low bound is agricultural BMPs and higher bound is municipal treatment facilities.
Tippett and Dodd (1995): No discount rate was applied and annual cost equals total lifetime costs adjusted by design life (varies by practice); "Ag. Lagoon" signifies aerobic lagoon and "Ag. Land" is land application (both with varying increasing over-application of land applied manure under pre-existing conditions). Cost-effectiveness values that assume direct discharge of animal wastes are not shown.
LCBP (2000): 1995: No discount rate was applied and annual cost equals total lifetime costs adjusted by design life (varies by practice); low bound is agricultural BMPs and high bound is larger industrial point source.

$5.92 per pound (Randall et al., 1999).[12] The range of these estimates is comparatively narrow given that the study examines a single retrofit category across similar facilities. The time frame for this analysis ranges from 1995 to 1998 according to the available case study data for each WWTP. A 20-year capital renewal period is assumed; interest and inflation rates of 6 and 3 percent, respectively, are used (Randall, 2000). The primary emphasis in this study is nitrogen,

[12]The costs per pound of additional nitrogen removed were flow-weighted to determine the average for each state and for all plants evaluated.

since the cost to upgrade for phosphorus removal is both configuration- and site-specific (Randall, 2000).[13]

Based on this analysis and other data from the Maryland Department of the Environment, EPA's Chesapeake Bay Program Office has derived a cost-effectiveness value for BNR of $3.64 per pound of nitrogen removed, as shown in Table E-8 (Wiedeman, 1998). Based on this information and the results of the Randall study, EPA's cost-effectiveness analysis assumes that an estimated cost to remove nitrogen of less than $4 per pound demonstrates cost-effectiveness.

A number of other studies have been conducted to assess the cost-effectiveness of various state-level programs to reduce nutrients in Wisconsin (NEWWT, 1994), Vermont (LCBP, 2000), and North Carolina (Tippett and Dodd, 1995). In Wisconsin, a series of studies were conducted to compare the cost-effectiveness of point and nonpoint source controls across 41 subwatersheds in the Fox-Wolf watershed in Wisconsin (NEWWT, 1994). These studies estimated the cost of reducing phosphorus and suspended solids (TSS) loads from municipal treatment facilities and agricultural sources. Baseline projections are compared to necessary reductions to meet future water quality objectives, as mandated by that State's current regulations. The base year for the analysis is 1990. Phosphorus removal costs for rural sources are estimated at $9.64 per pound, whereas municipal treatment facilities are associated with an average annual cost of $165 per pound of phosphorus removed (NEWWT, 1994).

The Lake Champlain Basin Program (LCBP) conducted a similar study to evaluate costs to meet Vermont's water quality goals. This study estimated phosphorus removal costs ranging from $270 to more than $1,000 per pound at a large municipal facility, compared to $440 to $544 per pound of phosphorus removed using agricultural BMPs (LCBP, 2000). The base year for this analysis is 1995. Another study by the Research Triangle Institute (RTI) assessed the cost-effectiveness of agricultural BMPs for North Carolina's nutrient trading program. Estimated costs ranged from $2.72 to $135.17 per pound of phosphorus removed using anaerobic lagoons, and $0.36 to $34.27 per pound of phosphorus removed for land application practices (Tippett and Dodd, 1995). Estimated costs reflect the wide range of costs associated with land application, given pre-existing practices at different types of operations. Costs summarized for this analysis span 1985 to 1994. Estimated values are shown in Table E-10.

For this analysis, EPA assumes LCBP's estimate of less than $10 per pound to remove phosphorus from discharge sources. This estimate is a conservative estimate given the range of estimates in the literature (Table E-10). In addition, observations by researchers at Virginia Tech who estimated removal costs for nitrogen at WWTPs conclude that it will cost about the same to remove a pound of phosphorus as it costs to remove a pound of nitrogen, if removing only one

[13]For conventional plug-flow activated sludge configurations, all that is required for phosphorous removal is the installation of relatively low-cost baffles and mixers; for oxidation ditches, the addition of an anaerobic reactor separate from the ditch is needed (Randall, 2000).

nutrient. If the facility is upgraded to remove both nitrogen and phosphorus, the cost typically will be only slightly more than the cost to remove nitrogen alone (Randall, 2000).

EPA's benchmark to compare the potential costs per pound of sediments removed is EPA's cost reasonableness test established by EPA in developing technology-based effluent limits for conventional pollutants (see 51 FR 24982). This benchmark measures the cost per pound of TSS and BOD (biological oxygen demand) removed for an "average" POTW with a flow of 2.26 million gallons per day (USGPO, 1986).[14] Indexed to 1999 dollars, these costs are about $0.70 per pound of TSS and BOD removed. EPA used this benchmark to evaluate the estimated cost per pound of TSS removed by municipalities in a recent EPA rulemaking, which estimated the range of costs for stormwater controls to be between $0.04 to $0.18 per pound of TSS removed (USEPA, 1999f). The NEWWT studies also estimated the average cost to reduce TSS, reported at $0.008 per pound removed from rural land and $4.61 per pound removed at municipal treatment facilities (NEWWT, 1994).

E.4.2 Cost-Effectiveness Results

Table E-7 presents cost-effectiveness results for the proposed BAT Option under both co-proposed scenarios, Scenario 4a (two-tier structure) and Scenario 3 (three-tier structure) with regard to nutrients and sediments. Also shown are the results for alternative regulatory options that were considered by EPA. Results shown in Table E-12 for select technology options, including the proposed BAT Option (Option 3 for beef and dairy subcategories, except veal, and Option 5 for the swine, veal, and poultry subcategories) and Option 3+5 (both Option 3 and 5 for all subcategories). Options are shown for four CAFO coverage scenarios, including CAFOs with more than 1,000 AU and CAFOs with more than 500 AU (two-tier structure), and operations with more than 300 AU, both under Scenario 4b and as defined under Scenario 3 (three-tier structure). The differences in CAFO coverage provide an upper and lower bound of the analysis to roughly depict the alternative NPDES scenarios.

The values in Table E-12 are average cost-effectiveness values that reflect the increment between no regulation and the considered regulatory options. All costs are expressed in pre-tax 1999 dollars. Estimated compliance costs used to calculate the cost-effectiveness of the proposed regulations includes total estimated costs to CAFOs and offsite recipients of CAFO manure (Section 5) and costs to the permitting authority (Section 10).

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[14]The technologies used for secondary treatment at POTWs removes both TSS and BOD at the same time. Estimating only the tons of TSS removed from secondary treatment is not possible.

Table E-12. Cost-Effectiveness Results by Select Regulatory Option/Scenario, Nutrients ($1999)

Option/ Scenario	Total Cost [a/]	Nitrogen			Phosphorus		
		Removals	Avg. C-E	Increm. C-E	Removals	Avg. C-E	Increm. C-E
	($mill.)	(mill. lbs.)	($/lb. removed)		(mill. lbs.)	($/lb. removed)	
ELG Option 3 (Beef/Dairy) and 5 (Swine/Veal/Poultry)							
>1000 AU	$688	136	$5.10	$5.10	280	$2.50	$2.50
>500 AU "Two-Tier"	$840	182	$4.60	$3.30	377	$2.20	$1.60
>300 AU "Three-tier"	$886	206	$4.30	$1.90	425	$2.10	$0.90
>300 AU (Scenario 4b)	$992	206	$4.80	undefined	425	$2.30	undefined
ELG Option 1 (All Subcategories)							
>1000 AU	$362	64	$5.60	$5.60	226	$1.60	$1.60
>500 AU "Two-Tier"	$442	90	$4.90	$3.00	303	$1.50	$1.00
>300 AU "Three-tier"	$474	106	$4.50	$2.10	339	$1.40	$0.90
>300 AU (Scenario 4b)	$509	106	$4.80	undefined	339	$1.50	undefined
ELG Option 3+5 (All Subcategories)							
>1000 AU	$1,793	136	$13.20	$13.20	280	$6.40	$6.40
>500 AU "Two-Tier"	$2,074	182	$11.40	$6.10	377	$5.50	$2.90
>300 AU "Three-tier"	$2,147	206	$10.40	$3.00	425	$5.10	$1.50
>300 AU (Scenario 4b)	$2,318	206	$11.20	undefined	425	$5.50	undefined

Options and Scenarios are described in Table 3-1.
[a/] Costs are pre-tax ($1999).

Under the proposed BAT Option, EPA estimates an average cost-effectiveness of nutrient removal at $4.60 per pound (two-tier) or $4.30 per pound (three-tier) of nitrogen removed. For phosphorus removal, removal costs are estimated at $2.20 or $2.10 per pound of phosphorus removed under each co-proposed alternative (Table E-12). EPA's estimated cost-effectiveness to remove nitrogen exceeds EPA's benchmark for nitrogen removal of $4 per pound, but falls within the estimated range of removal costs for this benchmark (as discussed Section E.4.1). EPA's estimated cost-effectiveness to remove phosphorus is lower than the benchmark established for phosphorus of roughly $10 per pound (discussed in Section E.4.1). Based on these results, EPA concludes that these values are cost-effective.

As shown in Table E-12, the average cost-effectiveness of each of the co-proposed alternatives is roughly equivalent or within the range of estimated removal costs compared to the alternative NPDES scenario 4b that would cover all CAFOs with more than 300 AU. However, the BAT Option is incrementally the most cost-efficient under the three-tier structure, estimated at $1.90 per pound of nitrogen removed and $0.90 per pound of phosphorus removed. Incremental cost-effectiveness values are higher under both the two-tier, estimated at $3.30 and $2.20 per incremental pound of nitrogen and phosphorus removed, respectively. Compared to the three-tier structure (Scenario 3), Scenario 4b removes no more pollutants, but has a higher cost and, therefore, an undefined cost-effectiveness value (Table E-12).

A comparison of the cost-effectiveness of the BAT Option to alternative ELG options show that estimated average cost-effectiveness of the BAT Option is slightly higher at the 1,000 AU threshold compared to the 500 AU cutoff (Table E-12). Costs and removals are more than twice as high under the more stringent Option 3+5 for all subcategories (Table E-12). Costs and removals are lower than under Option 1, but EPA chose not to propose Option 1 because it does not represent the best available technology (described in Section VIII of the preamble).

Table E-13 shows that the cost to remove sediments under the BAT Option is estimated at $0.003 per pound of sediment removal under both tier structures. This estimated per-pound removal cost is low compared to EPA's POTW benchmark for conventional pollutants of about $0.70 per pound of TSS and BOD removed ($1999). Option 1 results across the range of NPDES Scenarios are estimated at about $0.05 per-pound removal of sediments (Table E-13).

Tables E-14 and E-15 show the results of EPA's C-E analysis by major subcategory groupings (cattle, dairy, hogs, and poultry) for the BAT Option under the two-tier and three-tier structures, respectively. As these tables show, there is a wide discrepancy in cost-effectiveness among the sectors. In particular, the cost to remove a pound of nutrients is greatest in the hog and cattle (includes beef, veal, and heifer) sectors. The average cost-effectiveness of the BAT Option is more than $20 per pound of nitrogen removed in the hog sector and about $10 per pound of phosphorus removed in cattle sectors. Removal costs are less than $5 or less per pound of nitrogen/phosphorus respectively, in the dairy and poultry sectors (Tables E-14 and E-15).

Table E-13. Cost-Effectiveness Results by Select Regulatory Option/Scenario, Sediments ($1999)

Option/ Scenario	Total Cost [a/]	Sediments Removed	Average Cost-Effectiveness	Incremental Cost-Effectiveness
	($m 1999)	(million lbs.)	(average $ per pound removed)	
ELG Option 3 (Beef/Dairy) and 5 (Swine/Veal/Poultry)				
>1000 AU	$688	209,050	$0.003	$0.003
>500 AU “Two-Tier”	$840	299,708	$0.003	$0.002
>300 AU “Three-tier”	$886	335,456	$0.003	$0.001
>300 AU (Scenario 4b)	$992	335,456	$0.003	undefined
ELG Option 1 (All Subcategories)				
>1000 AU	$362	7,867	$0.046	$0.046
>500 AU “Two-Tier”	$442	11,856	$0.037	$0.020
>300 AU “Three-tier”	$474	11,886	$0.040	$1.093
>300 AU (Scenario 4b)	$509	11,886	$0.043	undefined
ELG Option 3+5 (All Subcategories)				
>1000 AU	$1,793	209,050	$0.009	$0.009
>500 AU “Two-Tier”	$2,074	299,708	$0.007	$0.003
>300 AU “Three-tier”	$2,147	335,456	$0.006	$0.002
>300 AU (Scenario 4b)	$2,318	335,456	$0.007	undefined

Options and Scenarios are described in Table 3-1.
[a/] Costs are pre-tax.

Table E-14. Cost-Effectiveness Results by Sector under the Two-Tier Structure (Scenario 4a)($1999)

Sector	Total Cost [b/]	Estimated "At-Stream" Removals			Average Cost Effectiveness		
		Sediments	Nitrogen	Phosphorus	Sediments	Nitrogen	Phosphorus
	($ millions)	(million pounds) [a/]			($/lb. removed)		
ELG Option 3 (Beef/Dairy) and 5 (Swine/Veal/Poultry)							
Cattle	$231	14,427	42	23	$0.016	$5.50	$10.00
Dairy	$179	5,050	38	81	$0.036	$4.80	$2.20
Hogs	$294	4,965	11	42	$0.059	$26.70	$7.00
Poultry	$135	275,266	90	231	$0.000	$1.50	$0.60
ELG Option 1 (All Subcategories)							
Cattle	$86	6,775	12	14	$0.013	$7.40	$6.00
Dairy	$105	4,745	28	68	$0.022	$3.80	$1.50
Hogs	$138	70	1	13	$1.977	$120.70	$10.90
Poultry	$113	266	50	208	$0.427	$2.30	$0.50
ELG Option 3+5 (All Subcategories)							
Cattle	$1,148	14,427	42	23	$0.080	$27.10	$49.50
Dairy	$354	5,050	38	81	$0.070	$9.40	$4.40
Hogs	$494	4,965	11	42	$0.099	$44.70	$11.80
Poultry	$277	275,266	90	231	$0.001	$3.10	$1.20

Options and Scenarios are described in Table 3-1. "Cattle" include beef, heifer, and veal operations. "Poultry" includes broiler, egg, and turkey operations.
[a/]Pound-equivalent removals are calculated from removals estimated by EPA's loadings analysis, described in the *Benefits Analysis* (USEPA, 2000d) and the *Development Document* (USEPA, 2000a), adjusting for each pollutant's toxic weight (as described Section E.3.1).
[b/] Costs are pre-tax and indexed to 1999 dollars using the Construction Cost Index (ENR, 2000).

Table E-15. Cost-Effectiveness Results by Sector under the Three-Tier Structure (Scenario 3) ($1999)

Sector	Total Cost [b/]	Estimated "At-Stream" Removals			Average Cost Effectiveness		
		Sediments	Nitrogen	Phosphorus	Sediments	Nitrogen	Phosphorus
	($ millions)	(million pounds) [a/]			($/lb. removed)		
ELG Option 3 (Beef/Dairy) and 5 (Swine/Veal/Poultry)							
Cattle	$234	14,434	44	24	$0.016	$5.30	$9.80
Dairy	$211	5,159	50	98	$0.041	$4.20	$2.20
Hogs	$274	5,822	12	48	$0.047	$23.60	$5.70
Poultry	$158	310,041	101	255	$0.001	$1.60	$0.60
ELG Option 1 (All Subcategories)							
Cattle	$87	6,778	12	15	$0.013	$7.00	$6.00
Dairy	$120	4,752	37	82	$0.025	$3.30	$1.50
Hogs	$134	79	1	14	$1.699	$108.40	$9.70
Poultry	$132	277	55	228	$0.477	$2.40	$0.60
ELG Option 3+5 (All Subcategories)							
Cattle	$1,150	14,434	44	24	$0.080	$26.20	$48.20
Dairy	$429	5,159	50	98	$0.083	$8.60	$4.40
Hogs	$463	5,822	12	48	$0.080	$39.80	$9.60
Poultry	$326	310,041	101	255	$0.001	$3.20	$1.30

Options and Scenarios are described in Table 3-1. "Cattle" include beef, heifer, and veal operations. "Poultry" includes broiler, egg, and turkey operations.

[a/]Pound-equivalent removals are calculated from removals estimated by EPA's loadings analysis, described in the *Benefits Analysis* (USEPA, 2000d) and the *Development Document* (USEPA, 2000a), adjusting for each pollutant's toxic weight (as described Section E.3.1).

[b/] Costs are pre-tax and indexed to 1999 dollars using the Construction Cost Index (ENR, 2000).